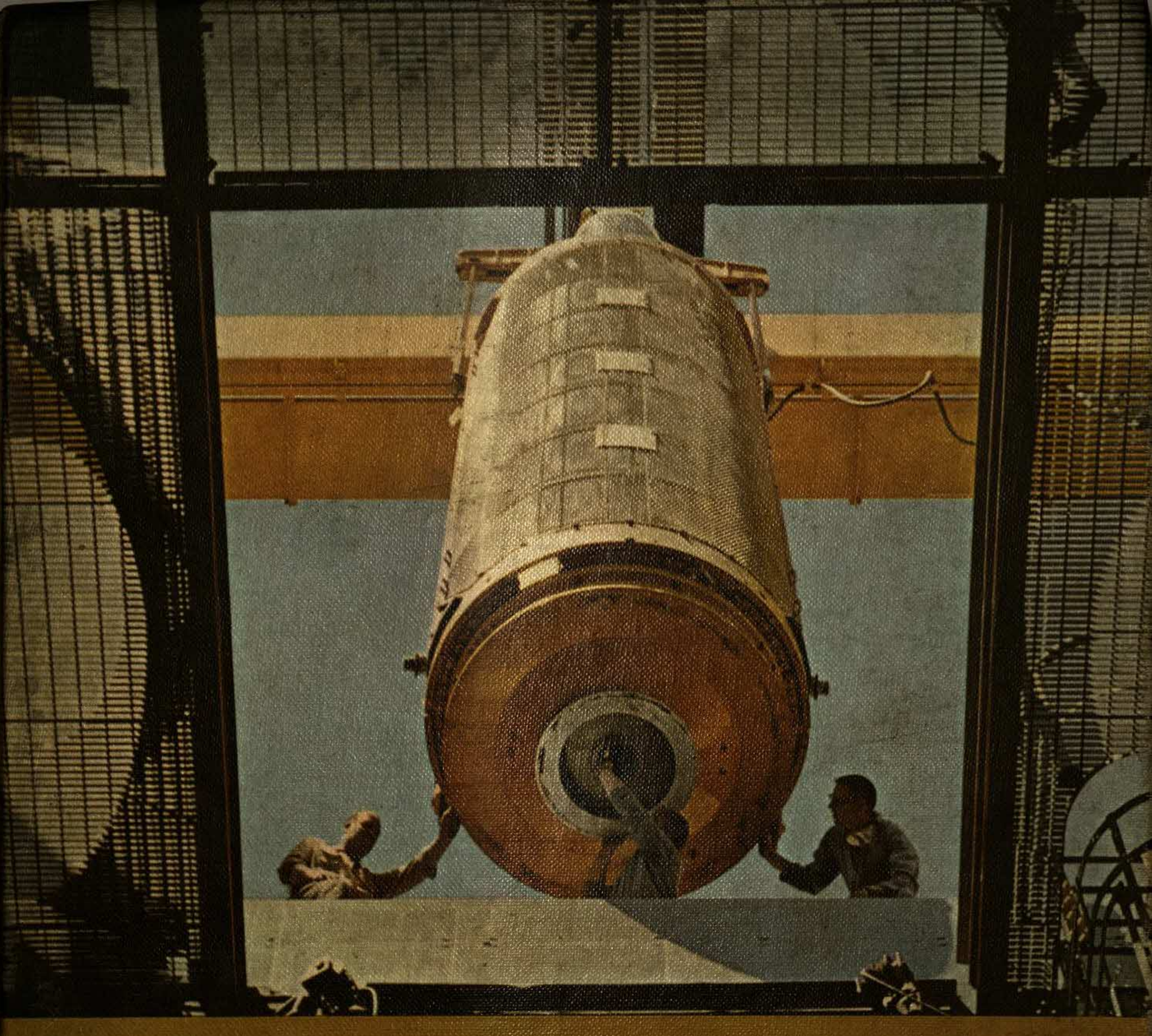

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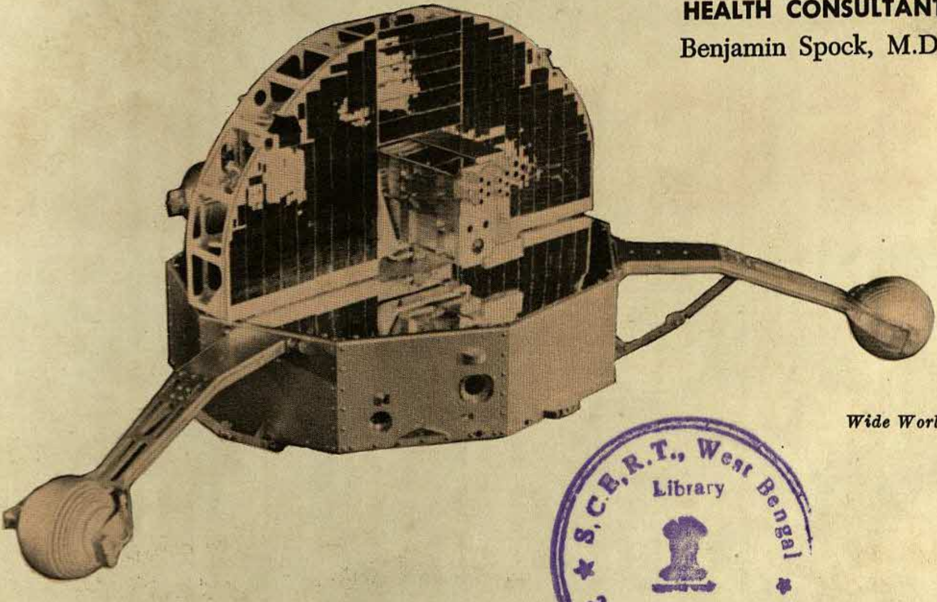

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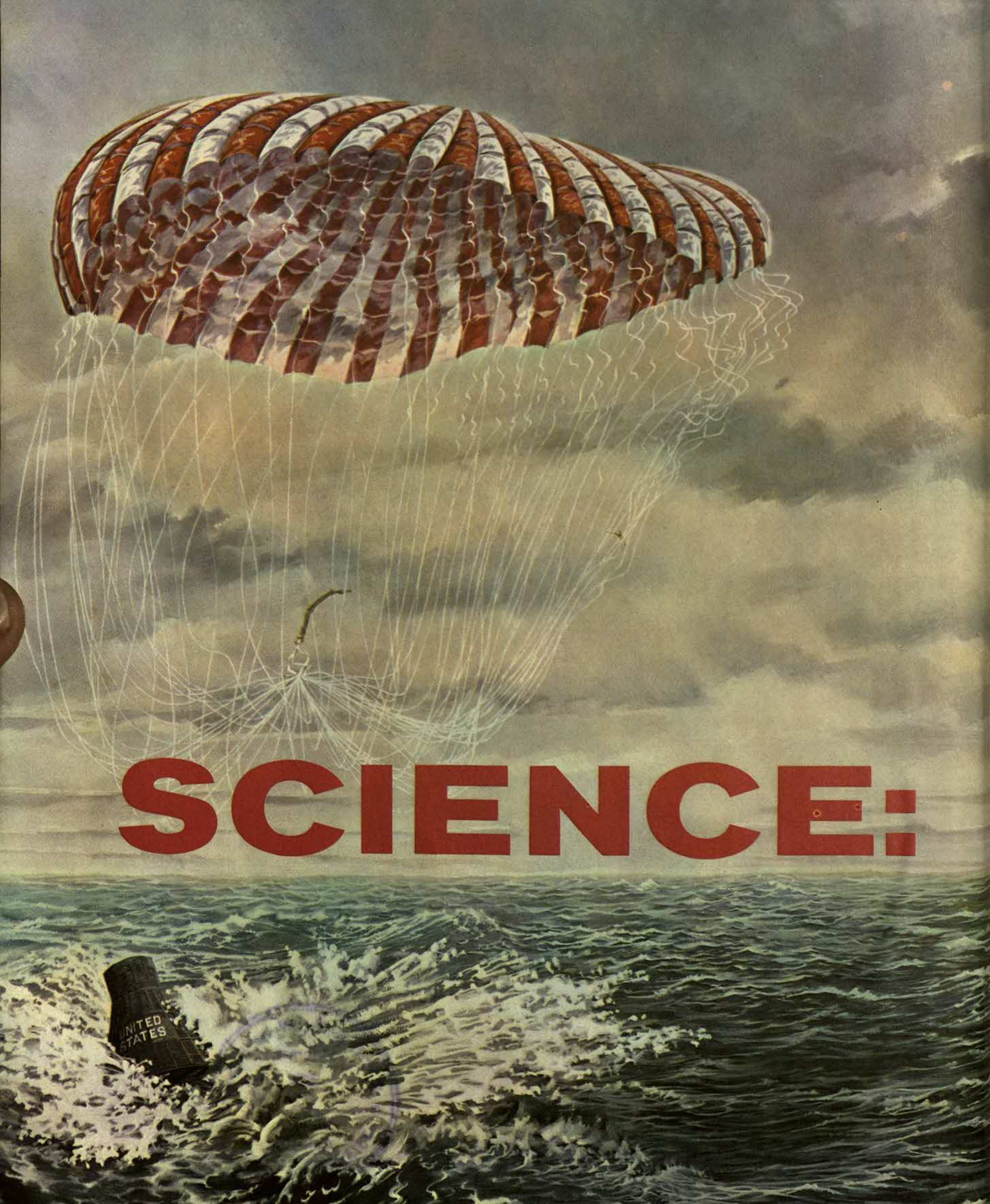

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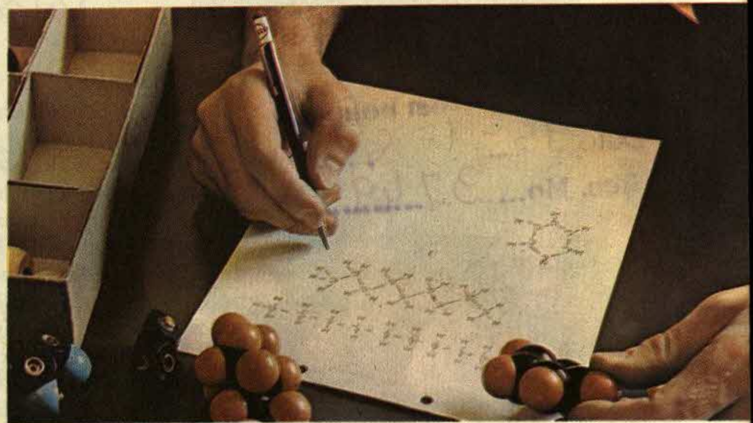
J. Darrell Barnard
*Chairman, Department of Science
and Mathematics Education
New York University, New York City*

Celia Stendler
*Professor of Education
University of Illinois, Urbana*

Benjamin Spock, M.D.
*(Health Consultant)
Professor of Child Development
Western Reserve University, Cleveland*

Lon Edwards
*Associate Professor of Science
Danbury State College
Danbury, Connecticut*



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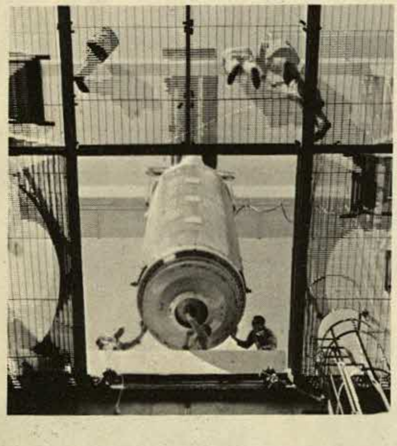

Science: A Search for Evidence
Science: A Way to Solve Problems
Science: A Key to the Future

Cover: First-stage Minute Man rocket being lifted from its casting pit. (McDonnell Aircraft Corp.) *Title Page:* Left, parachute jettisoning a space capsule after orbit. (McDonnell Aircraft Corp.) Right, scientist studying a scale model of compound (Standard Oil Co., N. J.).

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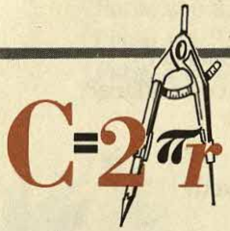

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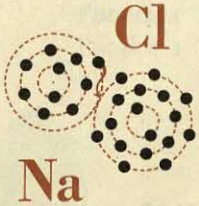

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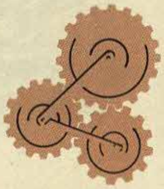

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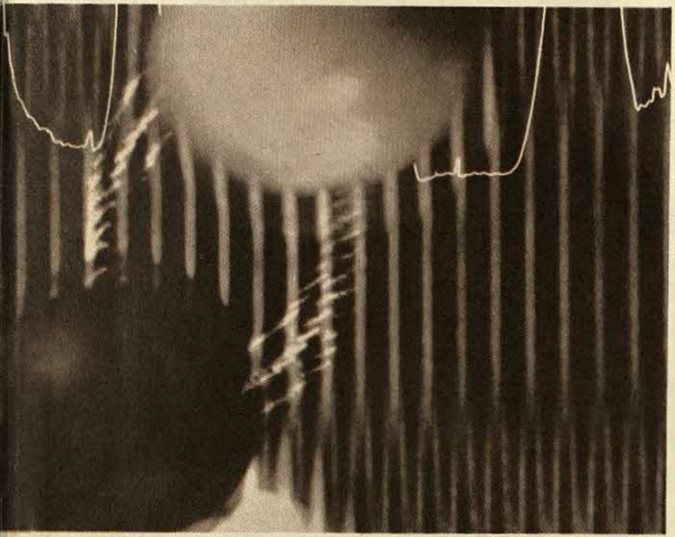

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UNIT 1

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Science and the Future

Scientific discoveries are changing the way in which people think about such things as space, the planet earth, and the living things upon it. New machines, which scientific discoveries have made possible, are changing many ways of doing things.

During this year, all who use this book will be studying science as a general subject rather than as a specific one such as chemistry. This approach is used to help you develop a broader understanding of science than would come from studying a specific science.

There are several parts to developing a broader understanding of science. One part has to do with how science—as one way of interpreting nature—is different from other ways. Another part of the understanding has to do with the ways in which scientific explanations of events in nature are developed and tested. A third part has to do with the ways in which mathematics is used in science. Each of these parts is considered as a separate problem in this unit.

Francis G. Mayer (In the Collection of the Corcoran Gallery of Art)

PROBLEM 1: WHAT IS SCIENCE?

Have you ever tried to answer the question, "What is science?" If so, you probably have found it difficult to give a simple answer. You might answer it by saying that science is concerned with nature—with the materials, forces, and living things in your environment. This is a good answer, but it doesn't go far enough.

ARTISTS, POETS, AND NATURE

Look at the picture on this page. It was painted by a famous artist. He, too, was concerned with nature—with blue sky, white clouds, distant mountains, and brilliantly colored autumn leaves. But a painter is not a scientist.

The artist is concerned with nature in a way quite different from the way of a scientist. The artist may reproduce on canvas not only what he sees, but something of what he feels when he views nature. He does not have to prove the accuracy of his painting.

The poet who wrote the poem on page 3 was also concerned with nature. But the poet is not a scientist.

The poet's interest in nature is also quite different from that of the scientist. He uses the sounds of words, the images they create, and the emotions they arouse to tell what he sees in nature and how he feels about it. No one expects him to prove that his word pictures and the feelings he has about nature are the ones which everyone must and should have.

NIGHT IN THE MOUNTAINS

by Eva Willes Wangsgaard

The hills took on the purple tones of
night
Against a red-gold sky the sunset left.
The canyon stream had woven all its
light
As fiery warp across the silver weft.
Small leaves stirred softly, shuddered in
the chill
Which crept down from the peaks; a
coyote's howl
Disturbed the sleepy birds; then all
grew still;
And color drained away on that long
vowel.
But water clung to light, a silver line,
Then blacked in shadow till a star came
through,
Climbed to the pinnacle of one tall pine,
And hung its tiny lamp there on the
blue.
It shimmered over canyons high and
steep,
Low-sheltered shadows, sighing pines,
and sleep.

THE SCIENTIST AND NATURE

The scientist, too, is concerned with describing the materials, forces, and living things in his environment. But he goes further. He tries to explain why things appear as they do.

Look again at the artist's painting on page 2. Scientists, too, have been concerned with the following questions: Why is the sky blue? What are clouds? How are they formed? Where did the mountains come from? Why do mountains in the distance appear to be blue? What causes the seasons? Why do leaves change color in the fall?

There are important differences between the way the scientist interprets nature and the way the artist and poet interpret it. The scientist's explanation must be reasonable in terms of what is already known about nature. Eventually his explanation must be acceptable to other scientists who put it to test.

One scientist has said that science is a way of putting questions to nature. Another has said that scientists are practically wringing nature's neck to get answers to their questions. Scientists generally agree that science begins with curiosity and questions about small, unexplained details in nature.

"What" Questions

Many of the questions that scientists have put to nature in the past have been "what" questions such as the following.

1. What are stars?
2. What are the different kinds of plants and animals?
3. What is the earth made of?

Through the ages, many attempts have been made to explain what the stars are. At one time, they were believed to be holes in the sky through which fires, thought to surround the earth, could be seen. Today it is believed that not all bright objects in the night sky are stars. Some are planets, comets, meteors, and artificial satellites. And there are a number of different kinds of stars, too. Astronomers have worked out a system for classifying the different kinds of stars.

In the past, much of the time of some scientists, such as biologists, has been spent in locating and naming hundreds of thousands of different kinds of plants and animals. But before the biologists could name the plants and animals, they had to work out ways of grouping them. In Unit 8, you will learn more about these systems for classifying plants and animals.

Efforts have also been made to describe what the earth is made of. At one time, it was believed that all things on the earth were made up of four basic materials—air, water, earth, and fire. Air, water, and rock are still considered basic materials of the earth. Today scientists believe that each of these is, in turn, made up of different things called ***elements.***

The chemist considers an element a substance that cannot be broken down into a simpler substance. Air is made up of a number of different elements, among them oxygen and nitrogen. Water is composed of two elements, hydrogen and oxygen. The different rocks are made up of various combinations of such elements as oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium.

At present, scientists know of more than 100 elements. All materials on the earth are made up of one or more of these elements. The material part of the earth is called ***matter.***

There are other phenomena on earth besides matter. One is light, which comes from fires when certain elements in materials are burned. Another is the electric current which comes from the materials in a dry cell, and which rings a doorbell. Still another is the magnetism which causes a compass needle to point in a northerly direction. There is gravity, which pulls objects toward the center of the earth. And there are electromagnetic waves which bring pictures and music to your TV set.

What are these phenomena? In some ways, they are quite different from the elements which make up air, water, and rock. You can't handle them in the same way. You can't contain light in a bottle as you can contain air or water. You can't pour an electric current into a bottle, as you can air or water. Light, electricity, magnetism, gravity, and electromagnetic waves the scientist describes as forms of ***energy.***

At first it seemed that the two groups of things were quite different. However, if you will reread the preceding paragraphs, you will see that in each kind of energy, matter is also involved in some manner. Scientists now believe that matter and energy are closely related.

"How" and "Why" Questions

If the scientist had done nothing more than answer the "what" questions about your environment, he would have added little to your understanding of it. You would have had names for heavenly bodies, plants and animals, and other things found on the earth. You might also have had descriptions of them, but not much more. You would have known little about how they behaved. You would have known nothing about why they worked, or why they behaved as they do.

You might have known that stars were hot bodies like our sun. You might also have known that the temperature of some stars is much higher than that of others.

You might have known all this without knowing how stars obtain their energy from atoms and why some stars are hotter than others.

By getting answers to "what" questions, you might have learned a lot about the appearance of each of the hundreds of thousands of different plants and animals. You might have known all of this without knowing how or why plants and animals came to be as they are today.

By getting answers to "what" questions about materials making up the earth, you might have known about all the elements and the names given to them. You might also have known that a distinction is made between matter and energy. But you would not have known how or why the elements react with one another. Nor would you have known why matter and energy are so closely related.

By answering "what" questions about the environment, scientists have been able to describe its many features and to name its parts. Only by answering the "how" and "why" questions have scientists been able to explain these things.

The "what" questions usually have to be answered first. Or, to put it another way, scientists generally first identify and describe aspects of the environment. Then they try to explain how, or why, these aspects are that way.

SUMMARY

Science is one of the ways by which nature is interpreted. Painting and poetry are other ways. Facts and explanations, to be scientific, must be proved through tests conducted by many scientists. The answers to "what" questions describe things. The answers to "how" and "why" questions explain things.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement. Do not write in this book.

1. Although artists may be interested in nature and paint pictures of it, they are not scientists because (a) only scientists understand nature (b) they do not have to prove the accuracy of what they see in nature (c) they have not studied science (d) all artists see things in nature the same way.

2. One way in which the activities of scientists, poets, and artists are alike is that they (a) must prove that their discoveries are true (b) see things the same way (c) may each be creative (d) must know about discoveries made in the past.

3. The answers to "what" questions about nature usually describe things that happen in nature rather than (a) explain them (b) name them (c) classify them (d) prove them.

4. It is now believed that matter and energy are (a) two entirely different things

(b) found only on the earth (c) closely related (d) not found in living things.

5. In the investigation of some new phenomenon, the first question that scientists try to answer is: (a) Where did it come from? (b) What is it? (c) How does it work? (d) Why does it behave as it does?

B. Examining Evidence

1. Make a collection of reproductions of pictures of waterfalls, mountains, trees, flowers, and the ocean, painted by different artists. After studying the paintings, answer the following questions.

   a. Do the scenes in the pictures look like ones with which you are familiar?
   b. How do these paintings differ from colored photographs of the same, or similar, scenes?
   c. How can you tell that all of the pictures were not painted by the same artist?

2. Make a collection of poems about trees, mountains, rivers, and storms. Arrange to have different members of the class read some of the poems aloud. Make a list of the words that the poets used to describe the things that they were writing about.

3. The launching of rockets and the exploration of the ocean floor are often described in newspapers and magazines by writers who are not scientists. In their writings they frequently tell how they feel about these happenings.

Collect articles such as these. Read them aloud to see if you can tell the difference between sentences which describe the actual event and sentences which describe how the writer actually feels about the event.

4. Artists often illustrate science books. Examine the illustrations in this and other science books. What kinds of things do the artists illustrate? Why do they illustrate them as they do? How do these illustrations differ from the paintings you have just examined?

PROBLEM 2: HOW DO SCIENTIFIC EXPLANATIONS DEVELOP?

The painting on page 2 was produced by an artist. It is not an actual scene. It merely represents what that person, the artist, saw. It is his interpretation of a scene. He might have imagined some things that were not in the original scene. He probably created color combinations which were more pleasing to him than the ones he actually saw. No other artist ever painted a picture exactly like this. For these reasons, it is said the artist's work is creative. He has created a painting quite different from any you have ever seen. If another artist should copy this painting exactly, you would not consider the work done by this other artist to be creative.

Scientific explanations come from men's minds. Development of these explanations requires imagination. The scientist who first thinks up an explanation is being creative in much the same way as the artist. There is an important difference, however. The scientist's explanation must be tested by other scientists. You can see how this actually works in science.

QUESTIONS THAT LEAD TO FACTS

Here are some "what" questions about ways in which matter behaves under different conditions.

What happens to your rubber heels after you wear your shoes for a while?

What happens to water when it is left in an uncovered pan?

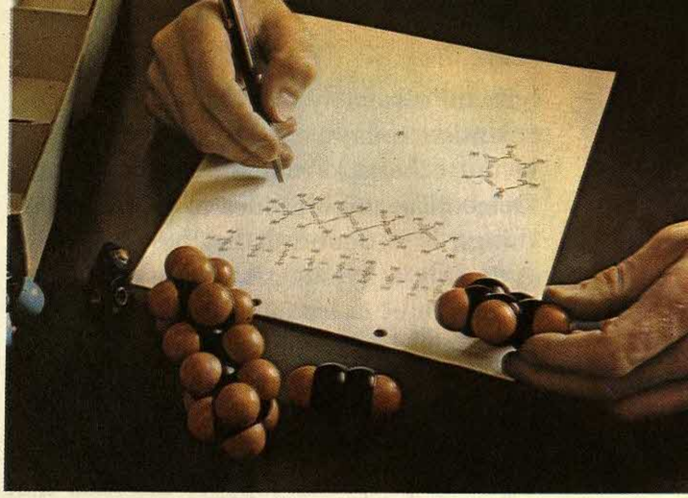
What happens to salt when you stir it in water?

What happens to your eyes when you peel an onion?

Observation of Facts

If you do not already know the answers to these questions, you can find them readily by observation. The rubber on the heels of your shoes slowly wears away. You are not conscious of the fact that the rubber is wearing away unless you notice that you are marking up the floors. If water is left in an open pan, it soon disappears. This happens although you can't see the water leave the pan. When salt is stirred into water, the salt seems to disappear. Your eyes smart when you peel an onion, even though you can see nothing passing from the onion to your eyes.

The answers to the "what" questions above are observed facts about different kinds of matter. They are descriptions of what happens. For the most part, these make up the facts of science. From your own experiences, you have accumulated many such facts. But facts alone do not explain how or why things happen as they do. To explain "why" requires more than simple observation of what happens. Here is where imagination and creativity begin to work in science.



Standard Oil Co. (N. J.)

A study of the scale model of a compound helps scientist to write its structural formula.

HYPOTHESES AND THEORIES

Scientific explanations generally do not originate in the mind of one person. The creative thinking of a number of people down through the ages usually contributes to the development of such explanations. Here again science differs from art.

Reason Versus Superstition

Many of our modern scientific explanations originated in the minds of people who lived hundreds of years ago. Democritus (dee-MAHK-rih-tus), a Greek philosopher, was born almost 2,500 years ago. Along with other Greek philosophers of his time, he tried to substitute for the myths and superstitions so common then reasonable explanations of events. He believed, and taught his students, that all things are made up of extremely small, indestructible bits of matter.

This was an idea that Democritus had to create in his mind. The imaginary bits are too small to be seen. He had imagined them. The idea was somewhat like a guess, but an extremely well-thought-out one. Scientists today consider such guesses to be ***hypotheses.*** From the way in which Democritus used his idea to explain many things, it is doubtful that he thought of it as only a hypothesis. There seemed to be no doubt in his mind that this was the truth, and he taught it as such.

About 400 years later, Lucretius (lyoo-KREE-shih-us), a Roman, wrote a poem *The Nature of Things.* He used the experiences of people to support the idea that all things are made up of invisible particles. Here is what he wrote.

> "Water dripping from the eaves hollows a stone, the bent ploughshare of iron imperceptibly decreases in the fields . . . but what bodies depart at any time the nature of vision has jealously shut out of our seeing. . . . Nature therefore works by unseen bodies."

The idea that matter is made up of invisible particles was developed further by Robert Boyle, an Englishman. He wrote a book in 1661, in which he used the idea to explain what happens in certain chemical reactions. Since that time, Democritus' hypothesis that all things are made up of small particles has been accepted by scientists. When this happens to a hypothesis, it becomes a ***theory.***

Refinement of Theories

Today the molecular theory of matter is accepted. This theory of matter differs in several ways from Democritus' hypothesis. Democritus believed that the bits (molecules) were indestructible, that is, that they couldn't be broken into smaller particles. As you will learn later, this part of his idea is no longer acceptable.

It is also believed that the molecules of all substances are in constant motion. Molecules move fastest in gases, slower in liquids, and slowest in solids. When anything is heated, the movement of the molecules is speeded up.

Theories to Explain and Predict

You can now use the molecular theory of matter to explain why water disappears (evaporates) from a pan. You can also use it to explain why water disappears faster when it is heated. The same theory can be used to explain why salt disappears when mixed with water and why your eyes smart when you peel an onion.

Scientific theories are also used to predict what will happen in a given situation. For example, if adding heat to water makes the molecules of water move faster and farther apart to form water vapor, a gas, what happens when you take heat away from this gas? What happens if you heat a closed container of air molecules?

Hypothesis Based on Knowledge

As stated above, an explanation of why or how things happen as they do is called a theory. Theories generally begin as hypotheses. Hypotheses and theories originate in the minds of imaginative people. But something more than imagination is required by the person who originates a hypothesis. He must be well acquainted with all the facts that are to be explained by the hypothesis. Once the idea of a hypothesis comes to him, he must be able to show how it explains all related facts. If the hypothesis fails to do this, it will be rejected, or accepted only temporarily until a better one is suggested.

The best hypothesis is the simplest one that explains most of the facts. The hypothesis that explains all related facts is the one that becomes the theory. It is difficult to make a really sharp distinction between hypothesis and theory.

You have probably heard such statements as: "Your idea is as good as anybody's." "I've just come up with a theory to explain why our winters are getting warmer." "It's only a theory; don't accept it." How would you judge these statements in the light of the preceding discussion of scientific hypotheses and theories?

Faith of the Scientist

So far the scientific process has been described primarily as it is carried on by scientists. But in back of the process is something that gets the scientist started. It has to do with what the scientist believes. He believes that things which happen can be explained. He also believes that they can be explained in ways which make it possible to predict what will happen under various known conditions. Can you tell why these particular beliefs have sometimes been referred to as the faith of the scientist?

SUMMARY

It takes informed and creative people to think of ideas which may explain why things happen as they do. This is one of the reasons why science is a creative human endeavor. Creative ideas may become hypotheses and, later, theories. Theories not only explain, but they make it possible for scientists to predict. The scientist has faith that eventually everything that happens can be explained. This faith keeps him going.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement. Do not write in this book.

1. If one artist copied the painting of another, he would (a) not be creative (b) produce a better picture (c) test the first artist's accuracy (d) be a creative artist.

2. Imaginative and creative thinking (a) are used only in art and literature (b) should never be used in science (c) should be discouraged if a person wants to become a scientist (d) are as important in science as in other fields of human endeavor.

3. Facts alone (a) give all the answers in science (b) may not explain how or why something happened (c) are what science consists of (d) are the only things that you can believe.

4. Democritus, who lived almost 2,500 years ago, was a Greek (a) artist (b) poet (c) philosopher (d) scientist.

5. Lucretius, who lived about 2,000 years ago, was a Roman (a) artist (b) poet (c) philosopher (d) scientist.

6. Robert Boyle, who lived some 300 years ago, was an English (a) artist (b) poet (c) philosopher (d) scientist.

7. Theories in science (a) help to explain why things happen as they do (b) cannot be depended upon since they are not facts (c) are not accepted by scientists (d) can never be proved.

8. Theories generally begin (a) as a fact (b) as a hypothesis (c) after everything is known (d) before there are any facts known.

B. Collecting Information

Find out something about such early Greek philosophers as Thales (THAY-leez), Anaximenes of Miletus (an-ak-SIM-uh-neez of mi-LET-us), Diogenes (di-OHJ-ee-neez), Empedocles (em-PED-oh-klees), Democritus, and Aristotle.

An encyclopedia will give you information about their ideas. These men were thinkers and performed no experiments. How did they differ from today's scientists? Why are they called philosophers?

PROBLEM 3: HOW DOES MATHEMATICS AID IN DESCRIBING THINGS?

Have you ever tried to describe something without using numbers in any way? Try to describe your house, or your apartment without using any numbers. Describe a person whom you have met recently without mentioning his height, weight, or age. To make this assignment even more difficult, give your description without using your hands to indicate dimensions. Without numbers it is difficult to describe things completely.

QUALITATIVE AND QUANTITATIVE DESCRIPTIONS

You can describe such things as the color of your house, or the nature of a personality without using numbers. Such descriptions are called *qualitative* descriptions. To be more accurate, however, you must use numbers. Descriptions that use numbers in describing things are known as *quantitative* descriptions.

Measurement

To give quantitative descriptions of things, measurement must be used. The description may involve simply the counting of parts. For example, an insect is described as an animal that has six legs and three body parts—head, thorax and abdomen. Or it may involve the counting of units of measurement. A certain bird, for instance, is described as being eight inches long. These quantitative descriptions give you more accurate pictures than if you were to say that an insect has several legs, or a bird is of medium size.

Related Measurements

Quantitative descriptions often require more than telling how many parts something has, or how long it is. If you wanted to give a quantitative description of a container, such as a jar or can, you might do it in several ways. You might give its height, width, and depth, or you could give its ***volume.*** You might describe its volume in terms of how many pints, or quarts, or gallons the container could hold. You might also describe its volume in cubic inches, or cubic centimeters. Inches, centimeters, and pints are called ***units*** of measurement.

There are many kinds of units for measuring different things. You are acquainted with the common units for measuring distance, such as inches, feet, and yards. These are units of the English system.

The Metric System

Another system of measurement, called the ***metric system,*** is commonly used by scientists. It is based on the decimal system, that is, it uses units of ten.

In the metric system, the ***meter*** is the unit for measuring length. The meter equals 39.37 inches. A centimeter, or 1/100 (.01) of a meter, equals .3937 inches, 2.54 cm equal one inch.

A ***cubic centimeter*** (cm^3) is the unit for measuring volume. ***Graduated cylinders*** marked off in cubic centimeters are used in laboratories to measure liquid volume.

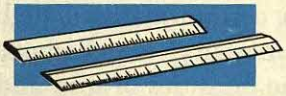
A ***liter*** is also used for measuring volume, or capacity. There are 1,000 cubic centimeters in a liter. One cubic centimeter, therefore, is 1/1,000 of a liter, or a ***milliliter.*** Scientists generally use the term milliliter rather than cubic centimeter for this unit of measurement.

A ***gram*** is the unit used for weighing materials. It takes about 453.6 grams to equal one pound avoirdupois.

At right are some important metric units used in scientific measurements.

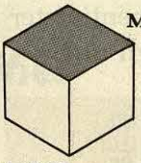
Nat. Bur. of Standards

Delicate balance scales like one above measures most minute quantities precisely.



MEASURES OF LENGTH

1,000 m = 1 kilometer (km)
1 m = 1 meter (m)
.01 m = 1 centimeter (cm)
.001 m = 1 millimeter (mm)



MEASURES OF VOLUME

1 cc = 1 cubic centimeter (cm^3)
.001 l = 1 milliliter (ml)
1,000 cc or 1,000 ml = 1 liter (l)

MEASURES OF WEIGHT

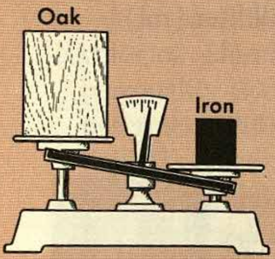
1,000 g = 1 kilogram (kg)
1 g = 1 gram (g)
.01 g = 1 centigram (.01 cg)
.001 g = 1 milligram (mg)

Density of Matter

By using units of measurement on page 11, the length, volume, and weight of matter can be described, as can the distance between objects. But there are other ways in which you describe things. For example, you may want to compare the weight of two substances such as iron and wood. It is quite common to say that iron is heavier than wood. But a large piece of wood may be heavier than a small piece of iron. To compare the weight of iron and wood, then, something else must be considered, namely, volume. The same volume of each material must be used in comparing their weights.

Generally, the cubic centimeter (cm^3) is used as the standard for measuring volume, and the gram for measuring weight. The weight, in grams, of a cubic centimeter of a certain material such as iron, water, or mercury, is called its ***density.*** Finding the densities of iron and wood is a precise way of comparing their weights. Below are densities of some materials.

There is something else which must be considered in determining the density of a material, and that is its temperature. Materials expand when heated. You would expect, therefore, that a cubic centimeter of water at 20°C would weigh slightly more than it would at 80°C. That is why densities of materials are always calculated at a standard temperature of 4°C.



DENSITIES

iron = 7.85 g/cm^3
platinum = 21.37 g/cm^3
oak = 0.7 g/cm^3
balsa = 0.12 g/cm^3
water = 1.00 g/cm^3
alcohol = 0.791 g/cm^3
gasoline = 0.66 g/cm^3
mercury = 13.596 g/cm^3

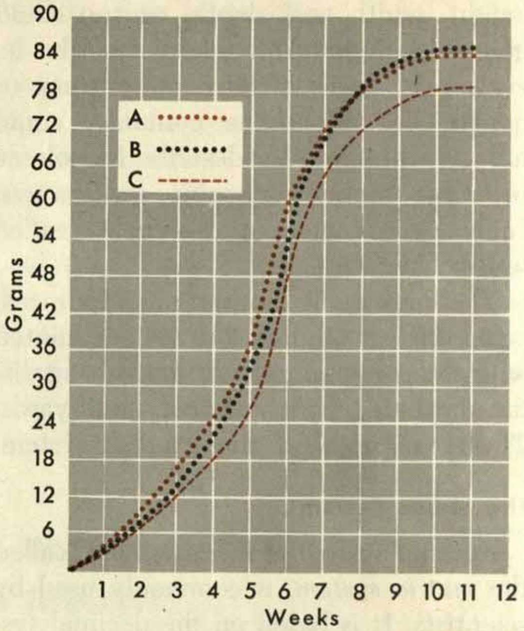


Chart shows rate of growth of a soy bean plant.

Measurements of Rates

In order to describe the speed of a moving object, you must use two measurements. One is the distance the object moves, and the other is the time it takes the object to move that distance. The speed of automobiles, airplanes, and rockets is described in miles per hour. This is the rate of movement.

Suppose that you wanted to describe how fast something, such as a corn plant, grew. Again you would have to measure two things: how much the plant increased in size and how long it took the plant to achieve that increase in size. In other words, you would have to determine its rate of growth.

DEPENDENCE OF SCIENCE UPON MATHEMATICS

Only a few of the many ways in which measurement is used in science have been described so far. Scientists believe that none of the materials and forces in the environment can be described properly without measurement. Some scientists hold to the belief that anything which exists can be measured. If it can't be measured, they doubt its existence.

The Need to Measure

When some scientists first got the idea that there were particles of matter smaller than the atom, they set about to describe them. They found, among other things, that some of the particles were extremely small and were negatively charged. They were not satisfied with such vague descriptions as "small" and "charged." They wanted to know how small they were and how much they were charged. An American physicist named Robert Millikan actually measured the weight and amount of charge of these particles. The negatively charged particles became known as ***electrons.***

Other Uses of Measurement

Throughout this book you will be introduced to other ways in which measurement is used. You will also learn more about the way the scientist uses mathematics to determine the relationship among things which he finds out by measurement. Without mathematics, there would not be science as it is known today. That is why anyone who plans to be a scientist must learn as much mathematics as he possibly can.

SUMMARY

In order to describe something accurately, measurement must be used. Standard systems of measurement have been developed. Scientists use the metric system. Mathematics is an essential part of science. To become a scientist, you must understand mathematics.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. When things are described by using numbers, the description is (a) inaccurate (b) qualitative (c) quantitative (d) altogether unscientific.

2. Qualitative descriptions do not deal with (a) numbers (b) color (c) appearance (d) form.

3. Scientists believe that none of the materials and forces in your environment can be described properly without (a) a microscope (b) a thermometer (c) measurement (d) a ruler.

4. In the metric system, the unit for weighing materials is the (a) centimeter (b) gram (c) meter (d) ounce.

5. When you say that iron is heavier than wood, you are talking about the (a) size (b) composition (c) color (d) density.

6. One of the faiths of the scientist is that (a) units of measurement actually exist (b) anything which exists can be measured (c) he will never be able to explain such things as gravity (d) he was born with knowledge of his environment.

7. Without mathematics there would be no (a) science as it is known today (b) forces in the environment (c) art as it is known today (d) energy on the earth.

8. An American scientist named Robert Millikan was the first to measure the charge and weight of (a) energy (b) light (c) a proton (d) an electron.

B. Analyzing Descriptions and Directions

1. Collect newspaper or magazine clippings describing things. Advertisements are a good source of such descriptions. In each of your clippings underline the descriptive words. Now tell whether the words give qualitative, or quantitative, descriptions.

2. Collect several recipes from a cookbook. Analyze each to find out what kinds of measurements are used to give accurate directions.

C. Comparing Ways of Measuring

1. Plan a demonstration to show that using a thermometer is a more reliable way of telling when water is warm or cool than by feeling the water with your hand.

2. Show that the position from which you read a ruler, a thermometer, or scale affects the accuracy of your reading.

3. Show that you can compare the weight of two rocks by measuring the distance each stretches a rubber band when the rubber band is used to lift them from the table.

4. The metric system includes measurements of length, area, volume, mass, velocity, density, and force. Only a few of the more common units are given on page 11. Refer to a large dictionary, or an encyclopedia, for help in preparing more complete tables of the units of the metric system. In each case indicate the English unit equivalent. Display these in your classroom, where you can refer to them.

D. Measuring Small Things

You can measure small things by putting a number of them together, measuring the total, and then dividing by the number of things. For example, you could get the thickness of a page of your book by measuring the thickness of 100 pages and then dividing that measurement by 100. When each member of the class has done this, compare results. Why could there be differences in results? What could be done to reduce the differences?

By using the above method of measurement, find the following:

1. The diameter of a piece of thread taken from a spool
2. Average volume of a water drop
3. Differences in the thickness of various kinds of paper
4. Average thickness of grass blade
5. Average diameter of radish seed

Unit Review

A. IDEAS ABOUT THE NATURE OF SCIENCE

By answering the following questions, you will review some of the important ideas in this unit.

1. How are the ways in which the poet and the artist interpret nature different from the ways of the scientist?
2. Can you explain the differences between the "what" questions and the "how-and-why" questions?
3. How are scientific explanations different from observed facts?
4. How does a scientific hypothesis differ from a mere guess?
5. How is a scientific theory used? Give examples.
6. What is the faith of the scientist?
7. What is the difference between qualitative and quantitative descriptions?
8. How is the metric system of measurement different from the English system?
9. What is the difference between the weight and the density of something?
10. How is the rate at which a satellite travels different from the distance which it travels?

B. WORDS IN SCIENCE

Tell how the words, or terms, in each pair below are related to one another, or explain the difference between them.

energy
matter

hypothesis
theory

qualitative
quantitative

meter
liter

You Can Go Further

A. By Studying Your Environment

A study of science should help you develop a better understanding of your environment. There are two parts to your environment—the natural part and the man-made part.

Prepare a one-page list of things in each part, arranged in two columns. In one column put those things in the natural environment and in the other, those in the man-made environment. Now compare the items in the two columns. Do this by drawing lines from each item in the second column to the item or items in the first column to which it is closely related. After you have done this, write a paragraph that tells how the man-made things in your environment are related to your natural environment.

B. By Using Formulas

1. In science, a mathematical formula frequently used is the formula for finding the area of a rectangle: $A = LW$. If L, the length, is 10 meters, and W, the width, is 5 meters, then A, the area is 50 square meters. Use this formula to solve the following:

   a) Find A when $L = .5$ meter and $W = .2$ meter.
   b) Find L when $A = 100$ square meters and $W = 15$ meters.
   c) Find W when $A = 30$ square meters and $L = 15$ meters.

2. $R = D/t$ is a formula which expresses the definition: Rate is the distance traveled per unit time. Which of the symbols (letters) in the formula represents rate? Is? Distance? Per? Time?

3. Write each of the following definitions as a formula:

   a) The rate of pay is total pay per unit of time.
   b) Pressure is the force per unit area.
   c) Power is the work done per unit time.

4. Make up problems that can be solved by each of the formulas in 3 above. Try these problems on your classmates.

C. By Making Graphs

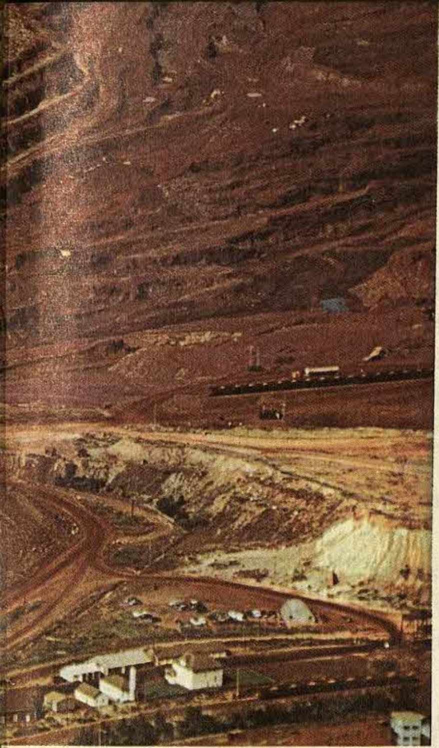
As you know, graphs can be used to help you see relationships that are not otherwise easy to see. In the following table is the length of daylight from sunrise to sunset in three American cities. The time is given in hours and minutes for each of the dates.

1. Plot length of daylight for each city on the same graph.
2. Use your graph to answer the following questions:
    a) In which city is there least variation in length of day?
    b) In which city is there greatest variation in length of day?
    c) Is the length of day ever the same in all three places?
    d) How do you explain the differences in the three curves?

Length of Day at Two-Week Intervals

Date		MIAMI	NEW YORK	ANCHORAGE
Jan.	1	10:37	8:58	5:21
	15	10:46	9:18	6:14
	29	11:01	9:50	7:30
Feb.	12	11:13	10:15	8:27
	26	11:33	10:59	9:56
March	12	11:55	11:44	11:25
	26	12:17	12:30	12:54
April	9	12:39	13:15	14:23
	23	12:52	13:44	15:22
May	7	13:12	14:24	16:50
	21	13:27	14:57	18:11
June	4	13:37	15:21	19:16
	18	13:41	15:29	19:45
July	2	13:41	15:27	19:36
	16	13:33	15:10	18:46
	30	13:20	14:41	17:31
Aug.	13	13:03	14:04	16:07
	27	12:42	13:23	14:39
Sept.	10	12:29	12:53	13:40
	24	12:07	12:08	12:13
Oct.	8	11:45	11:23	10:44
	22	11:24	10:40	9:17
Nov.	5	11:05	9:59	7:51
	19	10:54	9:35	6:57
Dec.	3	10:41	9:07	5:48
	17	10:36	8:54	5:11
	31	10:37	8:58	5:21

J. Barnell (Shostal)



George Hunter (Shostal)

UNIT 2

Matter and Energy

STATE INSTITUTE OF EDUCATION
Govt. of West Bengal

The world is made up of a seemingly endless variety of materials—air, water, rock, soil, animals, plants, plastics, and so on. The cave man had to use materials in the forms in which he found them. But over the centuries man has developed the technical knowledge, skill, and sources of energy required to adapt natural materials to his needs. By learning how to change their characteristics as well as their shapes, he has developed new materials. He has learned, too, how to change materials directly into usable energy.

Man has not always known how to do these things. But his explorations of natural materials to meet his needs have uncovered an even greater variety of them. At the same time, he has increased his skill in developing and manufacturing new materials. He has also discovered and put to use new sources of energy that his increasing demands required.

In this unit you will learn some of what man knows about the composition of materials, how they interact, and how energy can be obtained from them. It is this knowledge that has given man confidence in his ability to continue to improve the physical conditions under which he lives.

PROBLEM 1: WHAT DOES THE SCIENTIST MEAN WHEN HE SPEAKS OF MATERIALS AS MATTER?

As explained in Unit 1, those things that are made up of the elements are matter. Such things as light, magnetism, and gravity are forms of energy. At one time, it was believed that matter and energy were distinctly different. As more has been learned about them, scientists have come to believe that matter and energy are closely related. In fact, some scientists have suggested that the term ***mattergy*** be used to include both matter and energy.

MATTER

When scientists describe one group of phenomena as being different from another group of phenomena, their descriptions are often called ***definitions.*** Thus, an element is defined as a substance that cannot be decomposed into simpler substances. Similarly, efforts have been made to define matter in ways that would distinguish it from energy. One such definition has been that matter is anything that has weight and occupies space. Now examine this definition. Is it adequate?

Using this definition, it is not difficult for you to see that such things as water and rocks are matter. It may be difficult to accept gases, such as air, as matter. Recall a demonstration which proves that air occupies space.

Matter and Weight

Have you ever heard people say that everything that goes up must come down? Until 1959, that was true in terms of our experience with everything that was sent above the earth. But since 1959, many rockets sent into space have not returned. Their failure to return has caused people to revise many popular earth-bound ideas about matter and weight.

One of the most stubbornly held ideas has to do with ***gravity,*** the force that pulls things toward the earth. Man's experience with gravity has been largely limited to the way it behaves near the earth. You can examine it in another way.

GRAVITY

Suppose that you could take a position in space where you could closely observe the earth. Now imagine that you watched the paths of objects going up and coming down. This is the way man, on the earth, describes their movements. You would see that, regardless of the location of the earth, *up* was always away from the earth, while *down* was always toward the earth.

Center of Gravity

Now if you returned to the earth and wanted to explain what you had observed, how would you go about it?

First you could represent the earth as a small circle on a sheet of paper. Next you could use lines to represent the paths of the objects. Arrowheads on the lines would show directions. The situation would appear as in Figure A, page 21.

If you disregarded the upward paths and extended the downward paths into

5-304

the earth with dotted lines, the situation would be as in Figure B at right. All the downward paths into the earth would meet at the center of the earth. You could add as many paths as you wished. All would meet at the earth's center. Finally, you could imagine the pull on all of the earth's matter to be centered at a single point at its center. This point is called the ***center of gravity.*** The situation then becomes as in Figure C at right.

Models

Scientists often devise schematic drawings such as those on this page to represent something they are studying. The drawings and explanations of them are known as ***models.***

Scientists study a model to help them understand gravity and explain its effects on objects. Use the models in these ways as you study this unit.

Gravitational Field

Experience shows that falling objects near the earth tend to follow a path that can be represented as a straight line drawn through the object and the earth's center of gravity.

Since scientists believe that non-living objects do not move themselves, they explain their motion by imagining a ***force*** (a push or a pull) to be acting upon them. The force is directed along the line as shown. They call this force gravity. Furthermore, they believe that a falling object would continue to the center of gravity if it were not stopped by the earth's surface. All the space within which the earth's gravity acts upon objects is called the earth's ***gravitational field.***

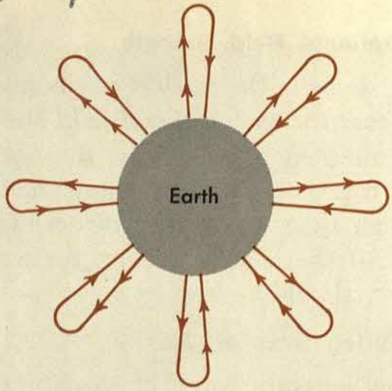


Figure A

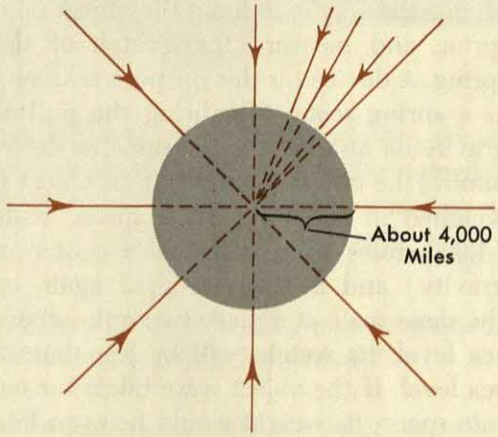


Figure B

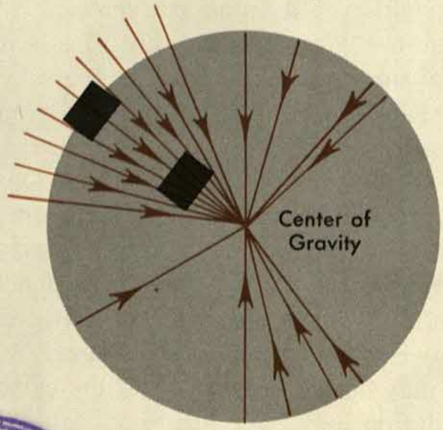


Figure C

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Gravitational Field Strength

The lines in the models can be used to represent the ***gravitational field strength.*** Near the center of gravity, the lines are close together. The field there should be stronger than where the lines are farther apart. If the field is weaker, the force of gravity should be less.

Measuring Force of Gravity

You measure force of gravity on an object by estimating how strongly that object is pulled toward the center of the earth. One way is to hang the object on a spring and measure the stretch of the spring. A device for this purpose is known as a ***spring scale.*** Measuring the pull of gravity on an object is the same as determining the object's ***weight.*** If an object is weighed at sea level on a spring scale (4,000 miles from the earth's center of gravity) and is then weighed again on the same scale at a place two miles above sea level, its weight will be less than at sea level. If the object were taken far out into space, its weight would be even less. Scientists believe the object could be taken so far from any celestial body that its weight would be almost zero.

You can demonstrate this idea with one of the models. Let the concentration of lines represent the gravitational field strength. The farther the lines are extended, the farther apart they are. Thus, the field becomes weaker, and the force of the earth's gravity should be less. It is assumed the earth's gravitational field extends out into space infinitely. At great distances from the earth, however, the field may become so weak that the earth's gravitation may have little noticeable effect on objects.

Newton's Law of Gravitation

In Unit 1, it was pointed out that it takes a truly creative mind to come up with explanations of why things happen as they do. Sir Isaac Newton had such a mind and he used it in an attempt to explain why things fall toward the earth and why planets are held in the orbits in which they travel around the sun. He thought up this idea about 300 years ago. Like many of the big ideas in science, it is a simple one. It was called the Law of Universal Gravitation. The important part of it was stated as: *Any two bodies attract each other with a force.* Another part stated: that *the attraction between two objects decreases as the objects are moved apart.* Newton calculated that doubling the distance between them reduced the attracting force to one-quarter of what it was before the objects were moved apart. (The distance is measured between the centers of gravity of the two objects.) This is an application of the law of inverse squares. From this statement it follows that if a satellite weighs 800 pounds on the earth's surface, it will weigh only 200 pounds 4,000 miles out from the launching pad. Can you see how this figure is arrived at?

A third part of the law states: *The larger the masses of the two bodies, the greater the force between them.*

Cavendish's Experiment

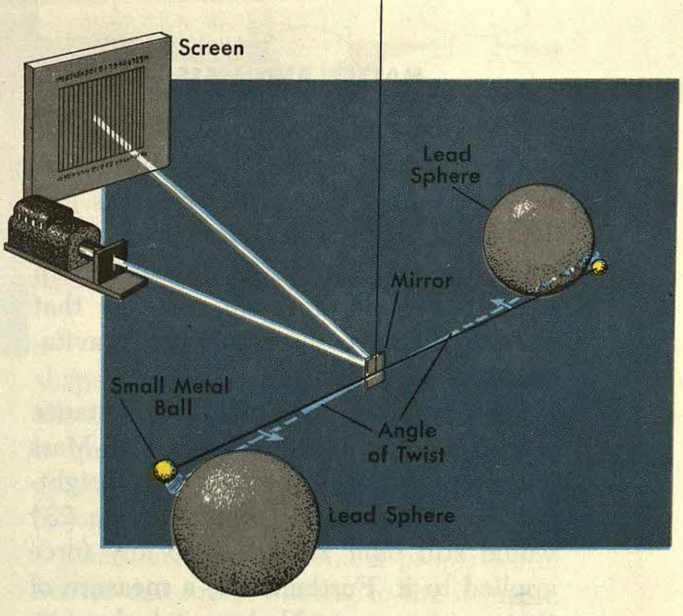
About 130 years after Newton stated the theory of universal gravitation, Henry Cavendish, another English scientist, set up experimental apparatus and measured the gravitational forces between two lead spheres. His results confirmed Newton's theory. On earth, scientists usually disregard the force of the smaller object and speak only of the earth's force as gravity. In astronomy and space science, however, the gravity of each body must be taken into account separately. (See Unit 6.)

Weightless Matter

Now go back to the definition of matter stated on page 4. Is it proper to say that weight is a property of matter? According to the theory of universal gravitation, all bodies in the universe attract all other bodies. If this is so, it is possible to imagine a point in space where all the gravitational forces would balance each other. An object in this spot would have a gravitational force of zero. It would be weightless. Would it still be matter, or would it vanish?

Objects can be made weightless by using motion to counteract gravity. Such would be the case of a person in the space chamber shown below. Does it seem reasonable to claim that the person ceases to exist simply because he becomes weightless?

It would seem that a more adequate definition of matter is needed.



Henry Cavendish, an English scientist, set up an apparatus like the one above for measuring gravitational forces between two lead spheres.

Man in space chamber tries to secure a bolt. Air-bearing platform puts him in a weightless state.

North American Aviation, Inc.

MATTER AND MASS

The weight of anything is determined by measuring the gravitational attraction between it and the earth. Scientists call this attraction gravity. But what does gravity pull on? Scientists give matter an attribute which they call ***mass*** so that matter will have something for gravitational forces to pull on.

Mass can be thought of as the resistance of matter to the action of any force. Mass is a property of all matter. That weightless object in space (refer to page 23) would still offer resistance to any force applied to it. Furthermore, a measure of that resistance would show it to be constant, regardless of the location of the object in space. Thus, when a body becomes weightless, it does not become massless, as you might think.

Basic Units

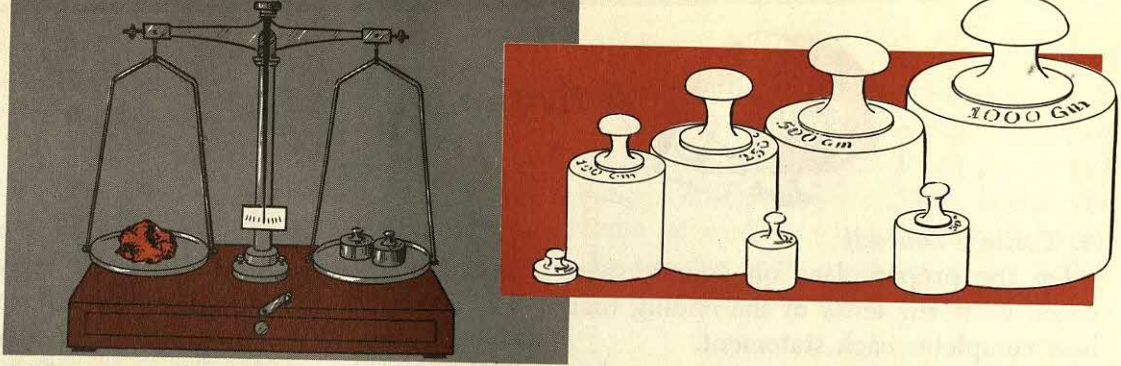
It is unfortunate that, in the confusion between mass and weight, the same name should have been used for the units in which each is measured. It had become common practice to speak of ***pounds of force*** and ***pounds of mass,*** of ***grams of force*** and ***grams of mass*** before the difference between force and mass was clearly recognized. To make it even more confusing, many people used the units pound or gram without stating whether they were dealing with force (weight) or mass.

The table gives the correct names of the corresponding units of mass, force (weight) and distance. All explanations and problems in this book will be in Metric-CGS or foot-pound-second (FPS) units. The FPS system is often called the English-Engineering, or English-Gravitational, System. In this system, a ***slug,*** the unit of mass, equals about 32.2 pounds. In the English-Absolute System, a ***poundal*** is a unit of force which can accelerate, or increase, the speed of a one-pound mass one foot a second. In the Metric-MKS, a ***newton*** is an absolute unit of force, which induces in 1 kilogram an acceleration of one meter per second per second. In the Metric-CGS, a ***dyne*** is a unit of force able to accelerate a one-gram mass one centimeter per second per second. One unit is the same for all systems—a unit of time. For most scientific work, this unit is the ***second,*** which is what the "S" stands for in MKS and CGS.

You have learned that an object has the same weight only when it is weighed at the same elevation and under the same conditions. For example, the difference in distance of New York City and of Denver, Colorado, from the center of earth's gravity results in a difference of more than one pound in weight in a ton of matter. In which city does matter weigh less?

The Basic Units

SYSTEM	MASS	FORCE	DISTANCE
Foot-pound-second	slug	pound	foot
English-Absolute	pound	poundal	foot
Metric-MKS	kilogram	newton	meter
Metric-CGS	gram	dyne	centimeter



Other Ways of Describing Matter

The scientist who is trying to determine the differences between various kinds of matter, such as oxygen and water, is not much helped by the knowledge that matter has mass and occupies space. He must have other ways of describing matter. Hence he lists the ***physical*** and ***chemical*** properties of matter.

Some physical properties of matter are its state (solid, liquid, or gas), its color, its odor, and its taste.

Density, as described in Unit 1, is a physical property of matter. You can now speak of density more exactly as the mass of substance per unit volume.

Closely allied to density is ***specific gravity,*** another physical property of matter. For a solid, this is usually the ratio of its density to the density of water. Water has a density of one gram per cubic centimeter (1 g/cm^3) in the metric system and about 62.4 pounds per cubic foot (62.4 lb./ft^3) in the English system. What would be the specific gravity of substances whose densities are given on page 12?

Other physical properties of solid matter are ***hardness, malleability*** (mal-ee-uh-BIL-ih-tee), ***tensile*** (TEN-sil) ***strength,*** and ***ductility*** (duk-TIL-uh-tee). Malleability is the capacity of a material to be shaped by hammering or by rolling. Tensile strength is the capacity of a metal to be pulled lengthwise without being torn apart. Ductility is the capacity of a metal to be drawn into threads or wires.

There are three chemical properties of matter that are of interest to the scientist. They are determined by these questions: (1) Is this matter chemically active? (2) How easily does this material combine with oxygen? and (3) Is this material an ***acid,*** a ***base,*** or a ***salt?*** Some of the answers scientists have found for these questions will be studied in later problems.

SUMMARY

Scientists define matter as anything that has mass and occupies space. In studying matter, it is important to distinguish between mass and weight. Mass is the resistance of unsupported matter to the action of a force. Weight is the pull of gravity upon bodies. The weight of a body may change, depending upon its position in the gravitational field. Its mass, however, remains the same. The mass and the space that matter occupies are expressed as a physical property called density. This is only one of the many properties of matter that have been studied to help scientists get a better understanding of it.

Activities

A. Testing Yourself

On the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. An "empty" water glass (a) has nothing in it (b) is full of air (c) is full of water (d) is being held upside down.

2. If matter occupies space, (a) a full pan of water does not overflow when an object that sinks is put into it (b) air is not pushed out of the way when an automobile drives along a street (c) the water level of a pond does not rise when you carefully put your head below the surface (d) an object that floats causes a full pan of water to overflow when it is placed on the water.

3. When a stone of 40 cm^3 volume is put into a graduated cylinder containing 250 cm^3 of water, the new volume reads (a) 40 cm^3 (b) 210 cm^3 (c) 250 cm^3 (d) 290 cm^3.

4. On the surface of the earth, "down" means (a) toward the center of the earth (b) any direction toward the earth (c) the same direction, regardless of where you are on the earth (d) one direction in the Arctic and another in the Antarctic.

5. In science, a model is (a) a picture (b) anything that moves (c) used to explain an idea (d) a person who poses for pictures.

6. The earth's gravitational field is strongest (a) on the earth's surface (b) at 5,280 feet above the earth's surface (c) at the earth's center of gravity (d) at the bottom of a deep mine.

7. All bodies in the universe exert a gravitational force on every other body (a) anywhere (b) at the earth's surface (c) in space (d) at the center of gravity of the earth.

8. If two objects ten feet apart are moved to a position five feet apart, they will have an attraction for each other that is (a) the same as it was in the first position (b) doubled (c) tripled (d) four times as great as it originally was.

9. The most accurate statement about matter and weight is that (a) the weight of a body of matter may not always be the same (b) matter always has weight (c) weight is a property of matter (d) matter is anything that has weight and occupies space.

10. A chemical property of matter is (a) rate of combination (b) color (c) density (d) state.

B. Applying Your Knowledge

1. Why is a man standing up in a canoe in danger? See if you can make a model of a system consisting of a man and a canoe, which will be safe. Where would the center of gravity have to be?

2. Find the center of gravity of an irregularly shaped solid. First hang the solid from three different points of suspension successively. While the object is suspended, drop a plumb line from each point in turn. Record the course of the plumb line by pencilling it on the surface of the object. After you have done this for the three suspension points, note where

the lines intersect. The point of intersection is the center of gravity. Why?

3. Use your knowledge of matter to analyze the properties and uses of the various materials listed below in Columns A and B.

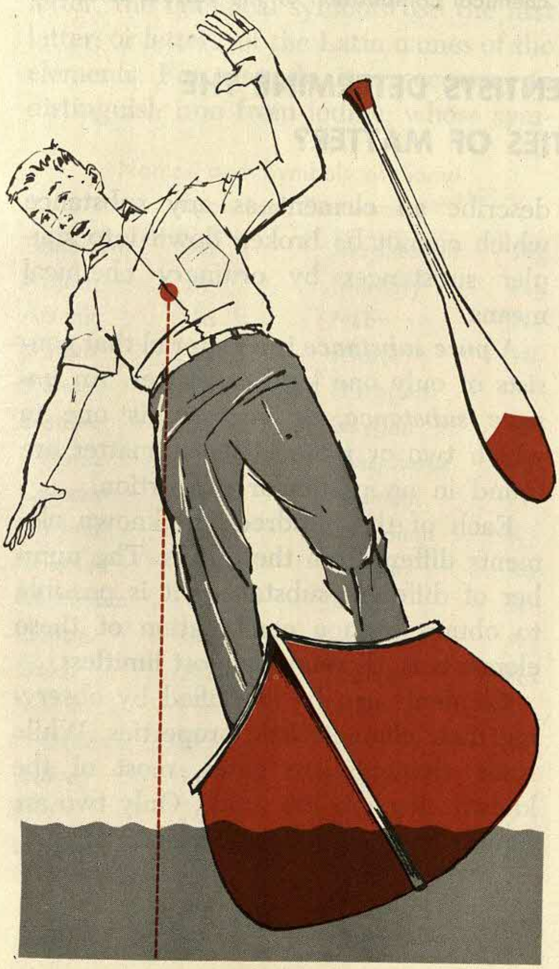
Several of the properties which these materials may possess are listed under A. A number of the uses made of these materials are listed under B. In the proper place on your answer sheet, beside the letter of each one listed under B, write the number of the property under A that is most closely related to that use.

A. Properties of Materials

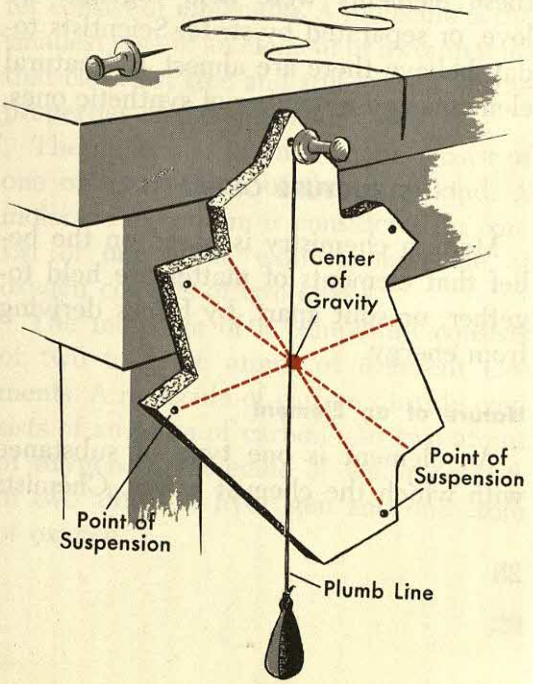
1. Malleability
2. Hardness
3. Tensile strength
4. Melting point
5. Magnetic properties

B. Uses of Materials

a. Supporting the roadway of a bridge
b. Wrapping candy with metal foil
c. Grinding tools
d. Pulling an elevator car
e. Making compass needles
f. Making containers to be used in a high-temperature furnace
g. Making metal sheets for automobile bodies
h. Sandpapering
i. Making ladles for handling melted steel
j. Making the core of a transformer



Why is the canoe off balance? What must canoeist do to restore balance and right canoe?



Chas. Pfizer & Co., Inc.

Research scientist uses a pipette to determine the chemical composition of the various solutions.

PROBLEM 2: HOW DO SCIENTISTS DETERMINE THE CHEMICAL PROPERTIES OF MATTER?

In the fifth century B.C., a Greek philosopher, Empedocles, claimed that all matter is made up of four elements—air, fire, earth, and water. He believed that these elements were held together by love, or separated by strife. Scientists today believe there are almost 100 natural elements and a number of synthetic ones.

STRUCTURE OF MATTER

Modern chemistry is based on the belief that elements of matter are held together, or split apart, by forces deriving from energy.

Nature of an Element

An element is one type of substance with which the chemist works. Chemists describe an element as any substance which cannot be broken down into simpler substances by ordinary chemical means.

A ***pure substance*** is a material that consists of only one kind of matter. An ***impure substance,*** or ***mixture,*** is one in which two or more kinds of matter are found in no particular proportion.

Each of the hundred-odd known elements differs from the others. The number of different substances it is possible to obtain from a combination of these elements is, therefore, almost limitless.

Elements can be identified by observing their characteristic properties. While some elements are gases, most of the known elements are solids. Only two are liquids at room temperature (22°C).

Elements are made up of atoms. An ***atom*** is considered to be the smallest part of an element that still has the properties of an element.

For convenience, chemists use an international language to represent elements. It is made up of ***chemical symbols.*** A chemical symbol consists of one or two letters representing one atom of an element. Thus, the symbol H stands for one atom of hydrogen and O stands for one atom of oxygen.

The letters are derived from the English, or the Latin, names of the elements. However, where the English names of a number of elements start with the same letter, the chemical symbols use the first letter, or letters, of the Latin names of the elements. For example, it is necessary to distinguish iron from iodine, whose symbol is I. The first two letters (Fe) of the Latin name for iron, *ferrum,* are, therefore, used as the symbol for iron. Notice that when two letters are used for a symbol, the first is a capital and the second is a small letter.

Names and Symbols of Some Important Elements

Aluminum	Al	Magnesium	Mg
Argon	A	Mercury	Hg
Arsenic	As	Neon	Ne
Barium	Ba	Nickel	Ni
Bismuth	Bi	Nitrogen	N
Bromine	Br	Oxygen	O
Cadmium	Cd	Phosphorus	P
Calcium	Ca	Platinum	Pt
Carbon	C	Potassium	K
Chlorine	Cl	Radium	Ra
Chromium	Cr	Silicon	Si
Copper	Cu	Silver	Ag
Gold	Au	Sodium	Na
Helium	He	Sulfur	S
Hydrogen	H	Tin	Sn
Iodine	I	Tungsten	W
Iron	Fe	Uranium	U
Lead	Pb	Zinc	Zn

Nature of Compounds

An element, as you have just learned, is a substance consisting of only one kind of atom. A ***compound*** is a substance consisting of two or more kinds of atoms.

A compound is formed when two or more elements unite chemically. When they combine, the elements lose their individual properties and form a compound which has its own properties. Because a compound is always composed of the same elements, which are combined in the same proportions by weight, a compound is always a pure substance. Chemical means must be employed to separate a compound into its constituent elements.

Nature of Molecules

Chemists believe that all kinds of matter consist of ***molecules.*** A molecule is the smallest part of an element or a compound that can exist free and still exhibit all the properties of the substance.

The molecules of an element consist of one or more atoms of the same kind. A molecule of sodium is considered to consist of one atom, while a molecule of oxygen consists of two atoms.

The molecule of a compound consists of two or more atoms of different elements. A molecule of carbon dioxide consists of an atom of carbon and two atoms of oxygen. A molecule of water consists of two atoms of hydrogen and one atom of oxygen.

The chemist uses a one- or two-letter symbol to represent one atom of an element. Because the molecules of a compound always contain the same number and same kinds of different atoms, a molecule can be represented by a ***chemical formula.*** A chemical formula consists of two or more symbols which represent the atoms composing one molecule of a compound.

If there is more than one atom of an element in a molecule, a subscript indicates the number of these atoms. A ***subscript*** is a number written below, and to the right of, the symbol of an element. If no subscript appears, the molecule is understood to contain only one atom of each element. Thus, the formula for water, H_2O, indicates that each molecule of water always contains two atoms of hydrogen and one atom of oxygen. If you wished to indicate five molecules of water, you would write $5H_2O$.

Nature of a Mixture

A third kind of substance, called a mixture, is merely a collection of different elements, compounds, or both. A mixture results from the mechanical stirring, or mixing together, of various substances. The substances making up a mixture retain their original identities and properties, and they may be separated by mechanical means. Many familiar substances, such as air, ice cream, concrete, milk, and wood are mixtures.

STRUCTURE OF THE ATOM

As you have previously learned, an atom is the smallest part of an element taking part in a chemical reaction. It cannot be broken down into smaller particles by ordinary chemical means. However, by using the modern techniques provided by nuclear science, atoms can be subdivided into simpler particles. Many of the particles which make up an atom are electrical in nature.

Dalton's Atomic Theory

In 1803, John Dalton, an English schoolteacher, made the following statements about atoms.

1. All matter is composed of extremely small particles called atoms.
2. The atoms of one element are all alike and are different from the atoms of all other elements.
3. Atoms may combine with other atoms.
4. Atoms cannot be further divided.

This last idea was not a new one. Democritus, in 400 B.C., claimed that matter was composed of "indivisible, indestructible particles, or atoms." This belief, which has existed in one form or another since then, is the only one of Dalton's four points which has undergone substantial change.

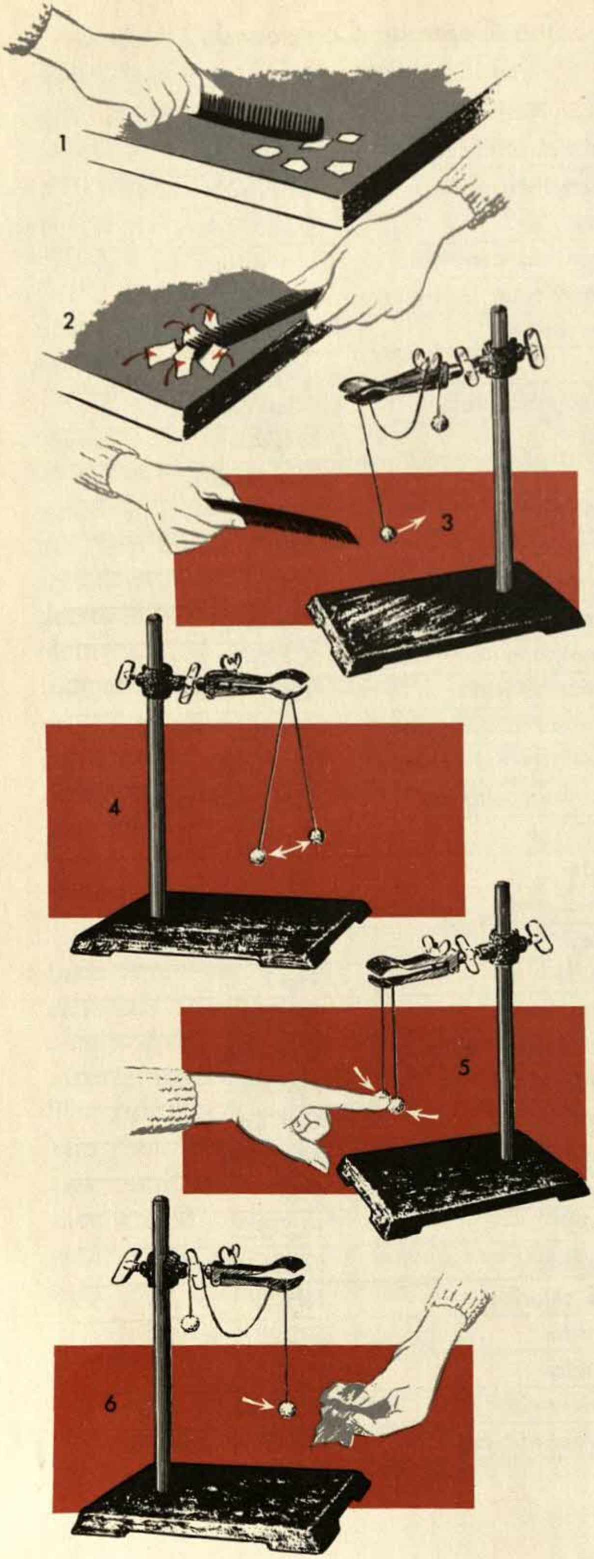
Electrical Charges

The old Greek philosophers knew that amber, which they called *elektron*, had the ability to attract lint and other small particles of matter to itself after it had been rubbed with wool. You will find that a hard rubber, or plastic, comb acts in the same manner.

Try the demonstrations described on page 32 to show the characteristic action of charged objects.

Names and Formulas of Some Common Compounds

Common Name	*Chemical Name*	*Formula*
Alcohol	Ethyl alcohol (ethanol)	C_2H_5OH
Ammonia water	Ammonium hydroxide solution	NH_4OH
Aqua fortis	Nitric acid, concentrated	HNO_3
Baking soda	Sodium hydrogen carbonate	$NaHCO_3$
Bauxite	Aluminum oxide	Al_2O_3
Benzol	Benzene	C_6H_6
Bleaching powder	Calcium oxychloride	$CaOCl_2$
Boracic acid	Boric acid	H_3BO_3
Cane sugar	Sucrose	$C_{12}H_{22}O_{11}$
Carbon dioxide	Carbon dioxide	CO_2
Carbon monoxide	Carbon monoxide	CO
Carbon tetrachloride	Tetrachloromethane	CCl_4
Chalk	Calcium carbonate	$CaCO_3$
Chloroform	Trichloromethane	$CHCl_3$
Dry ice	Solid carbon dioxide	CO_2
Epsom salt	Magnesium sulfate crystals	$MgSO_4 \cdot 7H_2O$
Ether	Diethyl oxide (ethyl ether)	$(C_2H_5)_2O$
Fire damp	Methane mixed with air	CH_4 with air
Grape sugar (glucose)	Dextrose	$C_6H_{12}O_6$
Hematite	Ferric oxide	Fe_2O_3
Hypo	Sodium thiosulfate	$Na_2S_2O_3 \cdot 5H_2O$
Iron pyrite (fool's gold)	Iron sulfide	FeS_2
Laughing gas	Nitrous oxide	N_2O
Limestone	Calcium carbonate	$CaCO_3$
Limewater	Calcium hydroxide solution	$Ca(OH)_2$
Lye	Sodium hydroxide	$NaOH$
Marble	Calcium carbonate	$CaCO_3$
Milk of magnesia	Magnesium hydroxide	$Mg(OH)_2$
Muriatic acid	Hydrochloric acid	HCl
Oil of vitriol	Sulfuric acid	H_2SO_4
Plaster of Paris	Calcium sulfate	$(CaSO_4)_2 \cdot H_2O$
Sal ammoniac	Ammonium chloride	NH_4Cl
Sand	Silicon dioxide	SiO_2
Soda water ("pop")	Carbonic acid	H_2CO_3
Vinegar	Dilute acetic acid	$H \cdot C_2H_3O_2$
Washing soda	Sodium carbonate crystals	$Na_2CO_3 \cdot 10H_2O$



1. Touch some scraps of paper about the size of a fourth of a dime with a dry hard rubber comb or a piece of plastic. Does anything unexpected happen?

2. Vigorously rub the comb with wool or fur. Again touch the pieces of paper. What do you observe now? Could it be that the rubbing did something to the comb? Or did it do something to the wool? (See 6.)

3. Use two eight-inch pieces of silk thread to suspend two small pith balls so that they touch each other. Again rub the comb with wool. Hold one of the pith balls to one side and touch the other with the comb. What do you observe?

4. Allow the other pith ball to swing against the ball you have just touched with the comb. Repeat parts three and four until you are sure of just what is happening.

5. Touch both pith balls with your hand for a moment. What does this do? Now rub the comb again and try to touch both balls at the same time. What do you observe now?

6. Rub the comb with wool. Use only one pith ball and touch it with the comb. Observe. Bring the wool near the ball. What action do you observe now?

When you rubbed the comb with wool, you apparently did something to the comb that made it attract scraps of paper and pith balls. It seems, too, that the two balls react to each other in the same way that either one does to the rubbed, or unrubbed, comb.

Assume, then, that when you rub the comb with wool, you put electrical charges onto it, and that some of these charges come off onto the pith ball when it touches the comb. If both the balls and the comb repel each other when they have the same charges on them, would this account for your observations of the actions of the pith balls in parts 4 and 5?

Kinds of Electrical Charges

All objects are normally electrically neutral, that is, they are neither positively, nor negatively, charged. If you assume all matter is composed of atoms, the atoms of neutral objects must be uncharged, or neutral. You might further assume that an uncharged atom possesses the same number of positive charges and negative charges. Under certain conditions, however, an atom may gain, or lose, negative charges and become electrically charged.

If the ball and comb in part 6, page 32, repel each other, but the ball is attracted to the wool, would it seem reasonable to infer that the wool does not have the same charges as those on the ball? You may even go so far as to say that such an object as the comb becomes electrically charged when it removes charged particles from the atoms of the wool. These particles can then arbitrarily be said to be ***negatively charged.*** Inasmuch as the atoms of the wool were assumed to be originally neutral, the wool is left with fewer negative charges than positive charges when negative charges are removed from it. The wool is then said to be ***positively charged.*** This statement should agree with your findings. The wool did react to the charged pith ball in a way opposite to the way it reacted to the charged comb.

As scientists considered these questions, they came to the idea that their observations could be explained if matter were assumed to be built of atoms from which it was possible to remove charged particles. Of course, no one had ever seen an atom, or any part of one. But scientists had developed their ideas from their observations by inference. And their idea of an atom composed of smaller particles has been accepted because it can be used to explain many observations.

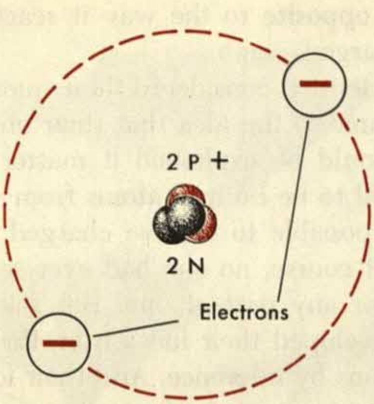
A negatively charged particle of an atom is called an electron in honor of the Greek philosopher's observation. The positively charged particle is called a ***proton.*** In 1932, a third, uncharged particle of the atom was discovered. It was called a ***neutron*** because of its electrical neutrality. It is assumed that there are still other parts to the atom besides electrons, protons, and neutrons.

THE BOHR ATOMIC THEORY

Niels Bohr, a Danish scientist, advanced a theory to explain the arrangement of particles within an atom. It is called the Bohr theory. The Bohr-Stoner atomic model represents the atom as Bohr conceived it. It is the model diagrammed on page 173.

Nucleus of Atom

At the very center, or core of the scientist's model of the atom, there is a compact, massive part called the ***nucleus,*** which gives the atom most of its weight. The nucleus contains the protons and



neutrons in an atom. A proton is estimated to be about 1/200,000,000 the size of a hydrogen atom. The neutron is about the same size.

A hydrogen atom has one proton in its nucleus. Helium, the next heavier atom, has two protons in its nucleus. Each succeeding heavier element has one more proton in its nucleus.

All atoms, except hydrogen atoms, have one or more neutrons in their nuclei. Although scientists have discovered a number of other particles which must be part of the nucleus, they have not yet completely learned what part they play in the make-up of the atom. It is evident that even though the atom is very small, it is complex.

Electrons in an Atom

Each atom, with the exception of hydrogen, has two or more electrons. Hydrogen has only one. An electron is considered to be larger than a proton, but has much less mass. Thus, while the proton is small, compact, and heavy, the electron is large, but much less massive than a proton.

There are as many electrons in an atom as there are protons in the nucleus of that atom; that is, the number of electrons equals the number of protons.

The number and arrangement of the protons and electrons within an atom determines whether the substance will be hydrogen, tin, gold, or another element.

Orbits of Atoms

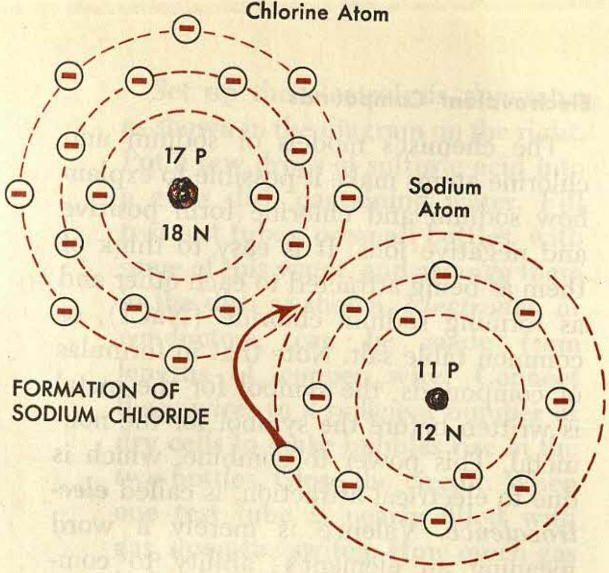
In the atomic model each electron revolves around the nucleus in one of the many possible paths, or planetary orbits, it may occupy. See page 49. Because the electrons are negatively charged and the protons positively charged, they are attracted to each other. It is this force of attraction which prevents the electrons from flying away from the nucleus as they revolve around it.

As the electrons circle the nucleus, they seem to wobble about within their orbits rather than to follow definite paths. Electrons traveling in orbits near the nucleus have less energy than those traveling in orbits farther away from the nucleus. Under certain conditions, electrons may jump from one orbit to another.

Protons, neutrons, and electrons are extremely small compared with the total size of an atom. The distances between the particles are many times greater than the sizes of the particles. Most of the atom is, therefore, empty space. Each atom may be thought of as a miniature solar system in which the nucleus represents the sun and the electrons the planets.

Making Comparisons

It may help you keep these ideas about the structure of an atom clearly in mind



Sodium and chlorine are shown forming salt.

if you consider that what you see depends upon your basis of comparison.

The earth, for example, appears to be standing still, but if you observed it from a point out in space, it would seem to have several motions. To the unaided eye, the edge of a razor blade appears to be smooth, but when viewed through a microscope, it is seen to be very rough. The wood used in the construction of your house seems to be solid, but a radio wave can pass through the wood as if it weren't there. Steel, too, appears to be quite solid both to the eye and to the radio wave, but an x-ray can pass through it. In making statements about the nature of the universe or the atom, therefore, you must always consider the size and position of the object in relation to the observer.

THE ELECTRON IN CHEMICAL BEHAVIOR

In the chemist's model of a molecule, atoms must be held together by some force. The observation that oppositely charged objects such as the pith ball and the wool attract each other suggests that the atoms of a molecule might possibly be held together by electrical forces.

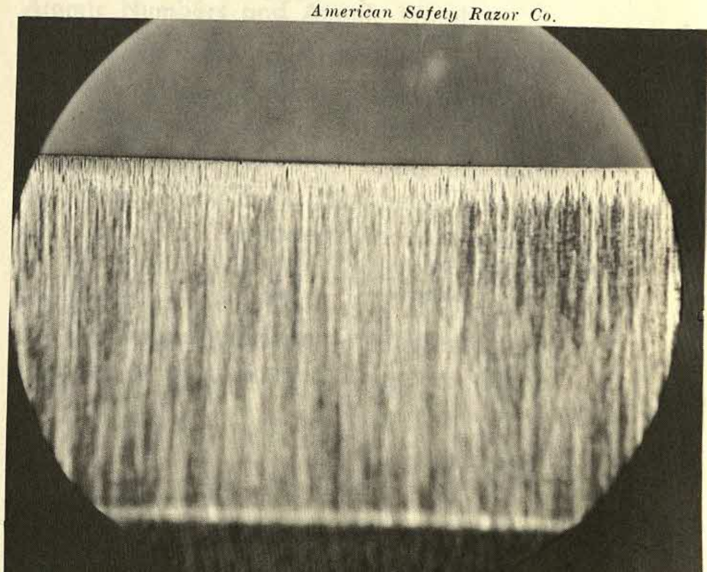
Formation of Compounds

The diagram at left shows a two-dimensional Bohr model for a sodium atom and a chlorine atom. According to the model, two electrons are needed for the first orbit, or ***shell,*** and eight more to complete the next orbit. The sodium atom has only one electron of its eleven electrons in its third, or outer, shell, and the chlorine atom has only seven in its outer shell. The electrons in the incomplete outermost orbit of an atom are called ***valence electrons.***

If, by chemical action, the valence electron of the sodium atom could be removed and placed in the chlorine atom, both atoms would become charged. The chlorine atom would now have one extra negative charge, and the sodium atom, having lost a negative electron, would now have a positive charge. Such charged atoms are called ***ions.***

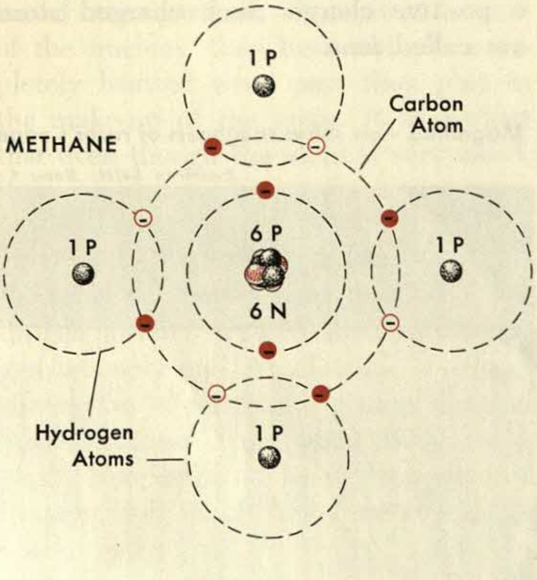
Magnified view shows roughness of razor's edge.

American Safety Razor Co.



Oppositely charged ions are found to attract each other. Atoms that have one, two, or three electrons in the outer shell, such as sodium or aluminum, form ***positive ions,*** and are known as ***metals.*** Those that need one, two, or three additional electrons to fill the outer shell, such as chlorine or iodine, form ***negative ions,*** and are called ***non-metals.*** Thus you can see that the chemical activity of elements depends upon the ease with which atoms gain or lose valence electrons.

The ion of chlorine in the diagram on page 35 has one extra electron, which it borrowed from sodium. This extra electron explains chlorine's combining power, or valence. Chlorine is said to have a valence of minus one (-1) and is written as Cl^-. Sodium, which has a positive valence of one, is written as Na^+. Hydrogen, H^+, is considered the standard of valence. Can you see that H^+ and Cl^- can combine to form a molecule of hydrogen chloride (HCl)?



Electrovalent Compounds

The chemist's models of sodium and chlorine atoms make it possible to explain how sodium and chlorine form positive and negative ions. It is easy to think of them as being attracted to each other and as forming sodium chloride ($NaCl$), or common table salt. Note that in formulas of compounds, the symbol for the metal is written before the symbol for the non-metal. This power to combine, which is due to electrical attraction, is called ***electrovalence.*** Valence is merely a word meaning an element's "ability to combine." Compounds formed by the transfer of electrons from one kind of atom to another kind of atom are called ***electrovalent compounds.***

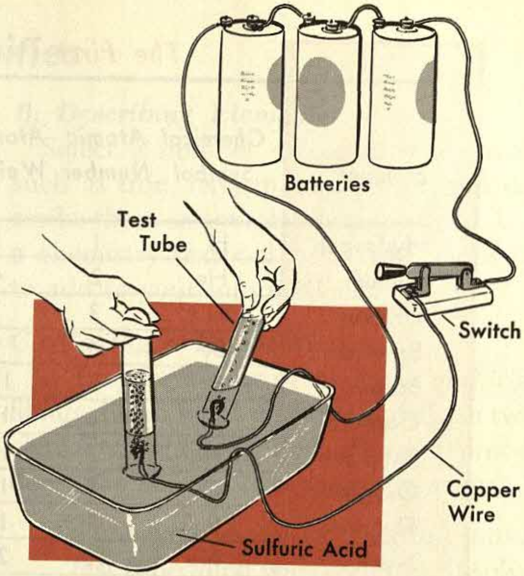
Covalent Compounds

Atoms may also combine to form compounds by equally sharing a pair, or pairs, of electrons. This sharing of electrons is called ***covalence,*** and the compounds formed in this way are called ***covalent compounds.*** In the compound methane (CH_4), which is shown at left, the carbon atom completes its outer shell by sharing the four electrons of the four hydrogen atoms. Each hydrogen atom completes its outer shell by sharing one of the four electrons in the outer orbit of the carbon atom.

When two atoms of hydrogen combine with one atom of oxygen, they form the covalent compound water (H_2O). This relationship is well demonstrated by the ***electrolysis*** (eh-lek-TROL-uh-sis) of water. Electrolysis is a way of separating a compound into separate substances by means of electricity.

Set up the electrolysis apparatus as shown in the diagram on the right. Put a few drops of sulfuric acid into a glass dish containing water. Fill two test tubes, or small bottles, with some of this water, and arrange them in the dish as shown. *Electrodes,* or conductors, can be made from lengths of copper wire. Connect these wires to a sufficient number of dry cells to make bubbles rise in the two bottles. Close the circuit. When one test tube is nearly filled with gas, open the switch. How much gas is in the other test tube? Place a glowing splint at the mouth of each test tube. At which test tube does it burst into flame? This test tube contains the gas oxygen. At which test tube is there an explosive "pop"? This test tube is filled with the gas hydrogen.

ELECTROLYSIS OF WATER



A Table of Common Valences

+	++	+++	−	−−
H				O
Li	Ca	Al	Br	S
Na	Cu	Fe	Cl	SO_4
K	Hg		I	CO_3
Ag	Mg	++++	OH	
	Pb Zn	C		

ATOMIC DIAGRAMS

The structure of an atom can be represented by a simple diagram in which the electrons are represented by a minus sign (−), the protons by a plus sign (+), and the neutrons by *N*. Since protons and neutrons are found in the nucleus of the atom, the symbols for these are written in the center of the diagram. Electrons are placed on planetary orbits, or shells. See page 34.

Note that in drawing a model of an atom, you must check to see that the number of protons in the nucleus equals the number of planetary electrons. It is this equality between positive and negative charges that makes an atom electrically neutral.

Atomic Numbers and Atomic Weights

Scientists have concluded, on the basis of a great deal of evidence, that all matter is electrical in nature. Furthermore, all atoms contain protons, neutrons, and electrons. They have also been able to determine the number of these particles in an atom and the so-called atomic weight of an element.

The ***atomic number*** of an element is the number of protons in the nucleus. Since

The First Twenty Elements

Element	Chemical Symbol	Atomic Number	Atomic Weight	Number of Protons	Number of Neutrons	Arrangement of Electrons in Orbits			
						K	L	M	N
Hydrogen	H	1	1	1	0	1			
Helium	He	2	4	2	2	2			
Lithium	Li	3	7	3	4	2	1		
Beryllium	Be	4	9	4	5	2	2		
Boron	B	5	11	5	6	2	3		
Carbon	C	6	12	6	6	2	4		
Nitrogen	N	7	14	7	7	2	5		
Oxygen	O	8	16	8	8	2	6		
Fluorine	F	9	19	9	10	2	7		
Neon	Ne	10	20	10	10	2	8		
Sodium	Na	11	23	11	12	2	8	1	
Magnesium	Mg	12	24	12	12	2	8	2	
Aluminum	Al	13	27	13	14	2	8	3	
Silicon	Si	14	28	14	14	2	8	4	
Phosphorus	P	15	31	15	16	2	8	5	
Sulfur	S	16	32	16	16	2	8	6	
Chlorine	Cl	17	35	17	18	2	8	7	
Argon	A	18	40	18	22	2	8	8	
Potassium	K	19	39	19	20	2	8	8	1
Calcium	Ca	20	40	20	20	2	8	8	2

an atom is neutral, the atomic number equals the number of planetary electrons in the atom. Scientists, using atomic numbers as a basis, have arranged the elements with atomic numbers from 1 to 103.

The ***atomic weight*** of an element is the sum of the neutrons and protons in the nucleus of an atom.

SUMMARY

Since early times, matter has been thought to be composed of indivisible elementary particles. This is still believed to be essentially correct. Air, fire, earth, and water are not the particles of matter on which modern science is based.

Molecules are considered to be made of atoms and atoms to be made of electrons, protons, neutrons, and other less well-defined particles.

The chemical properties of matter are mainly determined by the valence electrons, by which chemists explain how atoms combine to form compounds and how compounds decompose into elements.

Activities

A. Testing Yourself

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. Matter is considered to be made up of (a) molecules (b) earth, air, fire, and water only (c) hydrogen and oxygen (d) ions.

2. An elementary atomic particle which has no charge is the (a) electron (b) neutron (c) proton (d) photon.

3. Molecules composed of atoms of only one element are known as (a) compounds (b) atoms (c) pure substances (d) metals.

4. A symbol is used to represent (a) an atom (b) a molecule (c) a compound (d) a mixture.

5. A minus sign (−) indicates the charge on a (a) metal ion (b) molecule (c) non-metal ion (d) neutral atom.

6. Subscripts may be used to show the number of (a) molecules in an atom (b) atoms of an element in a molecule (c) elements in a molecule (d) elements in an atom.

7. Neutral atoms of a metallic element (a) are negative (b) are positive (c) are ions (d) have equal numbers of plus (+) and minus (−) charges.

8. The innermost shell of every atom is filled when it has (a) one electron (b) two electrons (c) seven electrons (d) eight electrons.

9. The ability of an atom to combine is called its (a) valence (b) shell (c) subscript (d) symbol.

10. A formula is used to represent one (a) atom (b) ion (c) molecule (d) element.

B. Describing Elements

Select a number of common elements such as iron, oxygen, and sulfur and describe them as completely as you can. Use a chemistry textbook or an encyclopedia to add to your information.

C. Making a Hypothesis

1. Prepare a mixture of sulfur and iron filings. From what you know of these two elements, which of the following procedures can be used to separate them again?

a. Shake some of the mixture into a test tube filled with water to dissolve the sulfur.

b. Spread some of the mixture on a glass plate and remove the iron with a magnet.

c. Heat some of the mixture in a test tube to melt the sulfur. Pour it off.

If you are not sure, check your procedure by performing it. (Some chemicals react violently with water, heat, or with one another. Ask your teacher if the procedure you plan to use in mixing these chemicals is safe.)

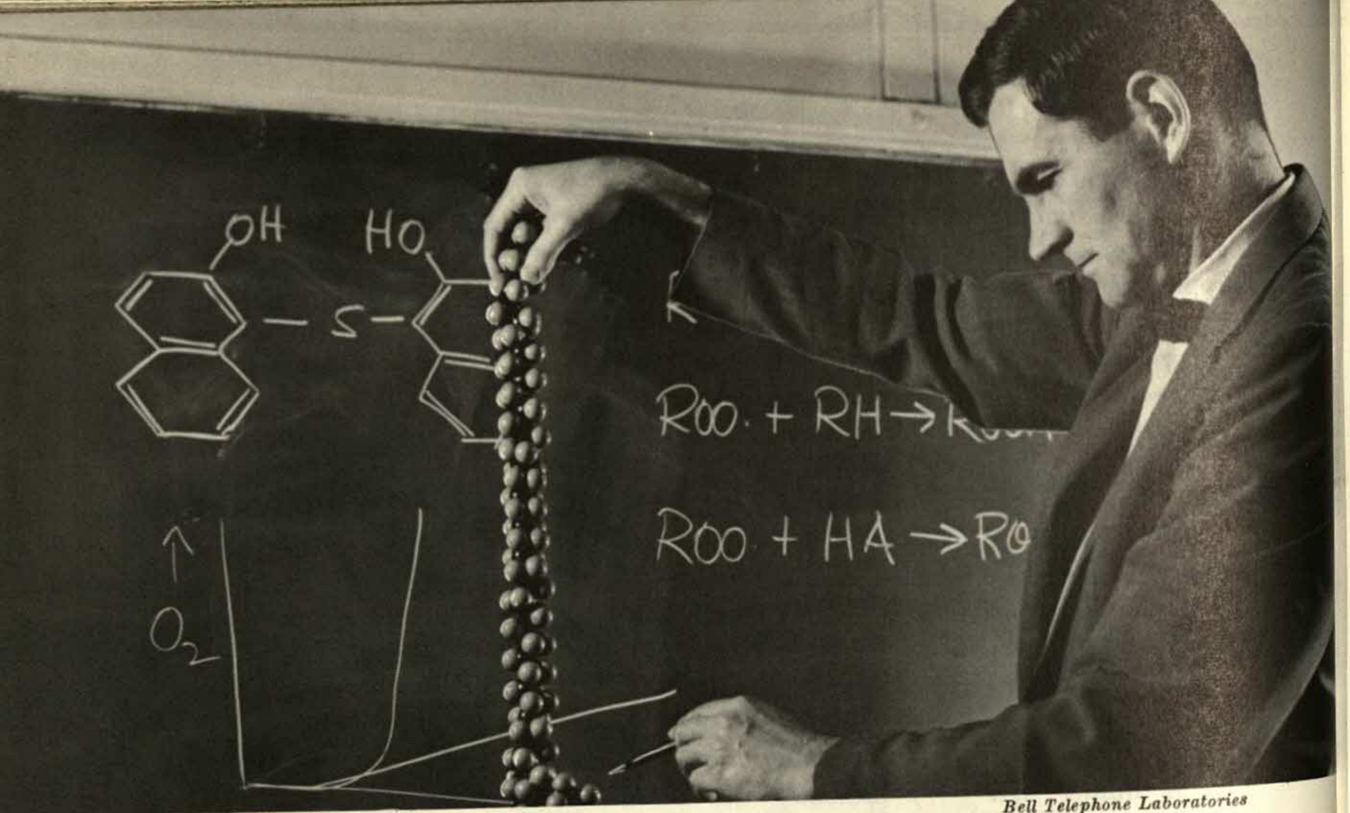
2. Dissolve some table salt in ten milliliters of distilled water in a test tube. If you apply heat to the solution to evaporate the water, will crystals of salt appear? Why?

D. Explaining Why and How

1. Why can't you write a chemical formula for milk or air?

2. How do molecules differ from atoms?

3. How does the addition or subtraction of a valence electron change an atom into an ion?



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PROBLEM 3: HOW ARE CHEMICAL CHANGES REPRESENTED?

Changes are going on about you all the time. Water changes to ice in the refrigerator, or to steam on top of the stove. Food changes when it is cooked. Metals rust or corrode, and paint fades. Some of these changes, such as the freezing of water, are called ***physical changes.*** A physical change is one which does not destroy the identity of a substance, or change its characteristic properties. A physical change is actually an ***energy change.***

Other changes produce materials that have chemical properties different from those of combining materials, whose identities are lost. Such a change is called a ***chemical change.*** For example, water is very different from either hydrogen or oxygen, the two gases that react chemically to form it.

The chemical properties of matter are best explained by describing the manner in which atoms combine. This explanation, in turn, depends upon the valence electrons. The real working unit in chemical changes, however, is the molecule. Molecules are best represented by formulas.

CHEMICAL FORMULAS

By knowing the valence of the elements, you can write correct molecular formulas for many compounds. On page 41 are suggested steps to follow.

1. Write the symbol for the metal and for the non-metal that are to be combined. Write the symbol for the metal first. Take, for example, the compound calcium chloride.

$$\mathrm{Ca\ Cl}$$

2. Place the proper valence signs after each element.

$$\mathrm{Ca^{++}\ Cl^{-}}$$

3. If one element has a smaller valence than the other, write symbols of enough atoms of the element with the smaller valence so that + and − signs are equal.

$$\mathrm{Ca^{++}Cl^{-}\ Cl^{-}}$$

The formula is written as $\mathrm{CaCl_2}$

4. In the special case in which neither atom has a valence of 1, you must increase the number of symbols for each element until the + signs and − signs are equal in number. Increase the symbols of the element with the larger valence first.

$$\mathrm{Al^{+++}\ O^{--}}$$

$$\mathrm{Al^{+++}\ Al^{+++}\ O^{--}\ O^{--}\ O^{--}} \text{ or } \mathrm{Al_2O_3}$$

$\mathrm{Al_2O_3}$ is called the ***empirical*** (em-PIR-uh-k'l) ***formula*** for aluminum oxide. An empirical formula is the simplest formula that can be written for a compound. The actual formula, or ***molecular formula***, shows the exact number of each kind of atom in a molecule of a compound. It may be the same as the empirical formula, or a multiple of it. It is determined by chemists only after very careful analysis and experimentation.

APPROXIMATE ATOMIC WEIGHTS

In many chemical processes in industry, it is necessary to know the relative weights of the chemicals to be used. How much coke, for example, must be added to a blast furnace to remove the oxygen from the iron ore? This can be determined if the formulas of the substances are known,

Modern chemistry demands high degree of measuring accuracy. Amount of hydrogen and carbon in ten chemical samples is weighed in small "boats" below, right. After compounds are burned in lab furnace, amount of gas collected in tube is weighed. Pounds are used to weigh coke, left.

E. I. duPont de Nemours and Co.

together with the ***approximate atomic weights*** of the elements involved.

Avogadro's Law

In the early 1800s, Amadeo Avogadro (ah-mah-DAY-oh ah-voh-GAH-droh), an Italian scientist, made the startling suggestion that equal volumes of different gases at the same temperature and under the same pressure contain the same number of molecules.

When the weights of equal volumes of oxygen and hydrogen gases were compared, it was found that the hydrogen weighed only 1/16 as much as the oxygen. From Avogadro's statement, now known as Avogadro's Law, it could be assumed that equal volumes of the gas contained the same number of molecules. If this were so, each hydrogen atom weighed only 1/16 as much as an oxygen atom.

Chemists decided, therefore, to use 16 to represent the approximate atomic weight of oxygen and to use 1 for the approximate atomic weight of hydrogen. Notice that these numbers have no units. They are relative to each other and may be called ***ratios.*** See page 38 for approximate atomic weights of some elements.

Until recently, the weight of oxygen gas, under a definite set of conditions, was taken as a standard for atomic weights. Now, the weight of one form of the element carbon is the substance against which the weights of elements are compared. This change in standard has caused only small changes in the atomic weights of the other elements.

In any given quantity of an element, there probably will be atoms of different masses (weights). Therefore the number, compared to a carbon atom, is an average and is only an approximate mass.

Percentage Composition of a Compound

In industrial processes, such as the removal of iron from its ore, large quantities of elements and compounds may be used in many different proportions to produce various other compounds. For ease in handling these large quantities of raw materials, it is convenient to know the percentage of each material in the desired product. The percentages are based on the atomic weights of the elements and the molecular weights of the compounds involved. To see how this works, calculate the percentage composition of a water molecule.

The water molecule (H_2O) has two hydrogen atoms, each with an approximate atomic weight of 1, and an oxygen atom with an approximate atomic weight of 16. The molecular weight of H_2O is, therefore, 18 ($1 + 1 + 16$).

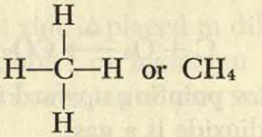
Since these weights are only ratios, any scale of masses may be used for measuring. If 2 pounds of hydrogen combine with 16 pounds of oxygen, 18 pounds of water will be formed, or 1,000 grams of hydrogen and 8,000 grams of oxygen will produce 9,000 grams of water. In the first example, the 2 pounds of hydrogen are $\frac{2}{18}$, or $\frac{1}{9}$, of the 18 pounds of water, and the oxygen is $\frac{16}{18}$, or $\frac{8}{9}$, of the total. A molecule of water is, therefore, 11.1% ($\frac{1}{9}$) hydrogen and 88.9% ($\frac{8}{9}$) oxygen. By the same method of figuring, carbon dioxide (CO_2) is 27.3 percent carbon and 72.7 percent oxygen.

STRUCTURAL FORMULAS

Chemists have found that a model-like ***structural formula*** is often of help in their work. A structural formula is one that indicates not only the kind and number of atoms, but a possible arrangement of the different atoms in the molecule.

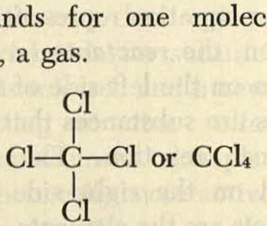
You can see by the examples of structural formulas below that a valence of 1 is shown by a line, or ***valence bond.*** A valence bond shows the valence for the atom at each end of it. Carbon (C) with a valence of 4 has 4 bonds, each of which can hold one atom of H, or of Cl, or of any other atom with a valence of 1.

STRUCTURAL AND EMPIRICAL FORMULAS



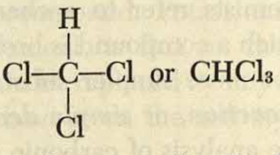
$$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{H{-}C{-}H} \\ | \\ \mathrm{H} \end{array} \text{ or } CH_4$$

This stands for one molecule of methane, a gas.



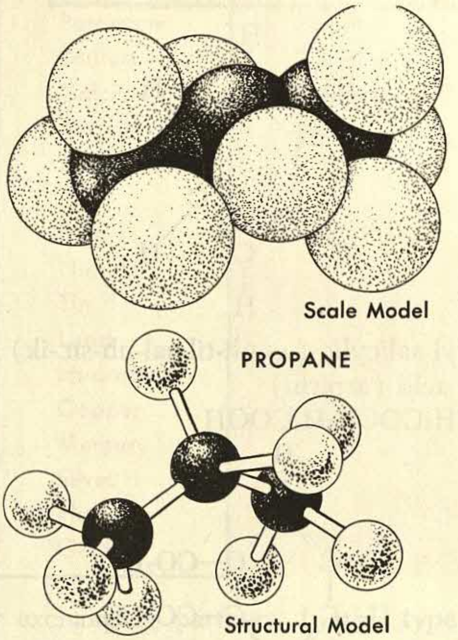
$$\begin{array}{c} \mathrm{Cl} \\ | \\ \mathrm{Cl{-}C{-}Cl} \\ | \\ \mathrm{Cl} \end{array} \text{ or } CCl_4$$

This stands for one molecule of carbon tetrachloride, used as a cleaning fluid, or in fire extinguishers.



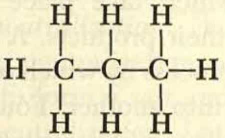
$$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{Cl{-}C{-}Cl} \\ | \\ \mathrm{Cl} \end{array} \text{ or } CHCl_3$$

This stands for one molecule of chloroform.



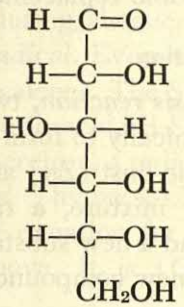
See if you can pick out the valence shown by the bonds for each atom in the following structural formulas of molecules.

propane gas
(C_3H_8)



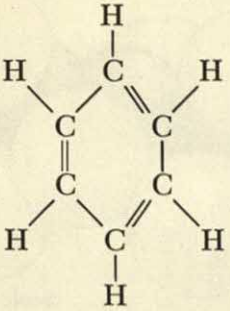
$$\begin{array}{c} \mathrm{H\ \ H\ \ H} \\ |\ \ \ \ |\ \ \ \ | \\ \mathrm{H{-}C{-}C{-}C{-}H} \\ |\ \ \ \ |\ \ \ \ | \\ \mathrm{H\ \ H\ \ H} \end{array}$$

dextrose sugar
($C_6H_{12}O_6$)

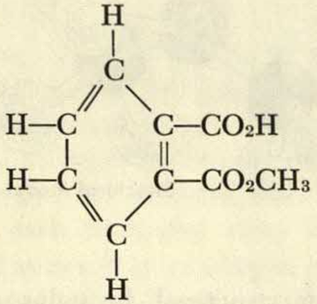


$$\begin{array}{c} \mathrm{H{-}C{=}O} \\ | \\ \mathrm{H{-}C{-}OH} \\ | \\ \mathrm{HO{-}C{-}H} \\ | \\ \mathrm{H{-}C{-}OH} \\ | \\ \mathrm{H{-}C{-}OH} \\ | \\ \mathrm{CH_2OH} \end{array}$$

benzene
(C_6H_6)



acetyl salicylic (AS-uh-til sal-uh-SIL-ik)
acid (aspirin)
$CH_3COOC_6H_4COOH$



TYPES OF CHEMICAL REACTIONS

A knowledge of the types of ***chemical reactions*** which take place is useful in predicting their products. A chemical reaction is a process by which one substance is changed into another. Four main types of chemical reactions are usually recognized—synthesis, analysis, single replacement, and double replacement.

Synthesis Reaction

In a ***synthesis reaction,*** two substances combine chemically to form a compound. If you mix zinc dust (Zn) and sulfur (S) and heat the mixture, a rapid reaction takes place and a new substance (ZnS) is formed. This new compound is a solid, as were the zinc and sulfur. However, it has none of the other physical, or chemical, properties of either zinc or sulfur. The chemist describes this reaction by this equation:

$$\text{zinc} + \text{sulfur} \xrightarrow{\text{heat}} \text{zinc sulfide}$$

$$Zn + S \xrightarrow{\Delta} ZnS$$

Read the equation as follows. When heat is applied, one molecule of zinc combines with one molecule of sulfur to yield one molecule of zinc sulfide and, also, heat energy. The arrow means "yields." The delta (Δ) indicates the heat energy needed to start the reaction.

Another example of synthesis is the burning in air of a fuel such as coke, which yields carbon dioxide.

$$C + O_2 \xrightarrow{\Delta} CO_2 \uparrow$$

The arrow pointing upward indicates that carbon dioxide is a gas.

In an equation representing a chemical reaction, the ***reactants*** (re-AK-tantz) are written on the left side of the arrow. Reactants are substances that enter into the chemical reaction. The ***products*** are placed on the right side of the arrow. Products are the elements, or compounds, produced by a chemical reaction.

Analysis Reaction

Chemists refer to a chemical reaction in which a compound is broken down into two or more simpler substances as ***analysis reaction,*** or ***simple decomposition.***

The analysis of carbonic acid (H_2CO_3) shows that it is composed of carbon dioxide combined with water.

$$H_2CO_3 \rightleftharpoons CO_2 \uparrow + H_2O$$

When two arrows, each pointing in opposite directions, are written in an equation, they indicate a ***reversible reaction.*** A reversible reaction is a type of chemical reaction in which the products, once formed, may recombine to form the original reactants.

Single Replacement

A ***single replacement,*** sometimes called a ***substitution,*** is a chemical reaction in which one free element substitutes for another already present in a compound. For a single replacement to take place, at least three elements must be present.

zinc + sulfuric acid ⟶
zinc sulfate + hydrogen

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \uparrow$$

If the metal zinc is placed in dilute sulfuric acid, bubbles of hydrogen gas are given off, and a solution of zinc sulfate remains.

Notice that the zinc has replaced hydrogen in the formula for sulfuric acid. Hydrogen gas is released and a new compound, consisting of zinc sulfate, is formed. This replacement takes place because zinc is chemically more active than hydrogen.

Elements are arranged in a list according to their ***activity.*** Activity means the ability of an element to replace another element in a compound. Potassium, the most active element, is first on the list. Any element can be replaced by any other that appears above it on the activity list.

Activity Series

Metals	*Nonmetals*
Potassium	Fluorine
Sodium	Chlorine
Calcium	Bromine
Magnesium	Iodine
Aluminum	
Zinc	
Iron	
Nickel	
Tin	
Lead	
Hydrogen	
Copper	
Mercury	
Silver	
Platinum	
Gold	

Double Replacement

In a ***double replacement,*** two compounds react to form two new compounds by exchanging partners. In this type of reaction, a metal must replace another metal, and a nonmetal another nonmetal.

$$\begin{array}{ccccccc} HCl & + & K(OH) & \longrightarrow & KCl & + & H(OH) \\ \text{acid} & + & \text{base} & \longrightarrow & \text{salt} & + & \text{water} \end{array}$$

The above equation represents a special type of double-replacement reaction known as ***neutralization*** (noo-truh-lih-ZAY-shun). In neutralization, an acid and a base react to form a salt and water. As a result of neutralization, both the acid and the base lose their properties.

A group of atoms which behaves as a single atom during chemical reactions is known as a ***radical.*** Every radical has its own definite valence. The SO_4 in the formula for sulfuric acid, H_2SO_4, acts as a unit and is, therefore, a radical.

A ***hydroxyl*** (hy-DROK-sil) radical is shown in the equation for a double replacement above. It is (OH). (Parentheses may, or may not, be used.) A hydroxyl radical is a ***monovalent,*** or one-valence, group made up of a hydrogen atom and an oxygen atom linked together.

BALANCING EQUATIONS

Each of the equations given for the four types of chemical reactions in the previous section is a ***balanced equation.*** A balanced equation represents the same number of atoms of each element on both sides. This equality is necessary because matter can be neither created nor destroyed. The next problem will discuss this theory which, while still true, now has a different meaning.

Procedure

Establishment of equality when balancing an equation is one of the fundamental procedures of chemical science. It is very simple to balance an equation if you follow the suggestions of scientists who do it regularly.

The first point to remember is that chemical reactions take place between molecules. By referring to the table on this page, you will see that molecules of compounds have two or more different kinds of atoms. Some elements, such as zinc, sulfur, and carbon, are considered as one-atom molecules. You will become familiar with these through use or by reference to an authoritative list. Another group consists of elements whose molecules are made up of two similar atoms. Most of these are gases. Common examples of formulas are given on page 31.

Decomposition

Refer to the electrolysis of water described on page 37. Set up the apparatus again and collect bottles of gas.

> **When one bottle is full of gas, how much gas is in the other one? What does this tell you about the formula for water? What happens when you light a wood splint, blow out the flame, and quickly slip it into the bottle that has the smaller amount of gas in it? What happens when you put a burning splint into the full bottle of gas?**
>
> **Examine the dry cells of the apparatus to determine what electrical charge the wire was carrying to the electrode in the full bottle of gas. What kind of ions, plus or minus, should be attracted to this electrode?**

Write and balance the equation for the reaction described above. Apparently water can be broken down into two gases. The acid ions do not need to be shown in your equation. The only gases possible are hydrogen and oxygen. Write:

$$H_2O \longrightarrow H + O$$

Formulas of Some One- and Two-Atom Molecules

Aluminum	Al	Lithium	Li	Bromine	Br_2	Iodine	I_2
Carbon	C	Sodium	Na	Chlorine	Cl_2	Nitrogen	N_2
Calcium	Ca	Sulfur	S	Fluorine	F_2	Oxygen	O_2
Mercury	Hg	Zinc	Zn	Hydrogen	H_2		

After writing the proper molecular formulas for all substances, the equation is:

$$H_2O \longrightarrow H_2\uparrow + O_2\uparrow$$

Is this equation balanced? To check this, you must think in terms of the numbers of atoms. There are two atoms of hydrogen on the left and two on the right. There is one atom of oxygen on the left and two on the right. That extra atom of oxygen came from somewhere. It must have come from the water. You will, therefore, have to add a second water molecule on the left. Now you have:

$$2H_2O \longrightarrow H_2\uparrow + O_2\uparrow$$

Having made a change, you must start at the left again and repeat the checking process. Now there are two atoms of hydrogen in each of the two molecules of water, so you have a total of four atoms of hydrogen on the left. How can four atoms of hydrogen be represented on the right? They could show as two molecules of H_2. This gives you the following equation:

$$2H_2O \longrightarrow 2H_2\uparrow + O_2\uparrow$$

Maybe this is correctly balanced, but it must be checked through once more because you made a change in the equation. As it now stands, there are four atoms of hydrogen on the left and the same number on the right. There are two atoms of oxygen on the left (in two molecules of water) and two atoms of oxygen on the right. The equation is balanced.

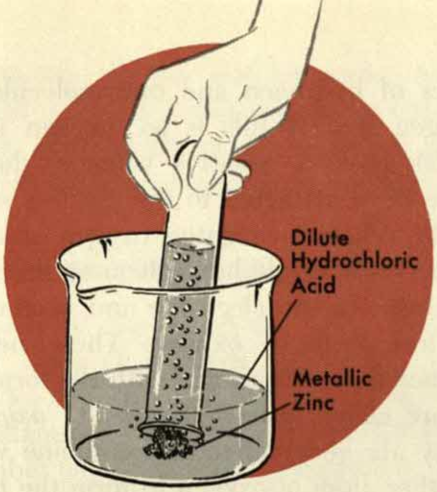
Meaning of Balanced Equation

What does this balanced equation tell you? It shows that the decomposition of two molecules of water yields two molecules of hydrogen and one molecule of oxygen gas. If this is so, oxygen ions, which have a negative valence, should have been attracted to the positive electrode. When the negative oxygen ions got there, each should have given up its extra electrons to the electrode and become a neutral atom of oxygen. These newly formed atoms of oxygen with the formula O are called ***nascent*** (NASS-n't) ***oxygen.*** They are very active and combine with another atom of oxygen to form the two-atom molecule of oxygen gas ($O_2\uparrow$) that you saw bubbling up at the positive electrode.

At the same time, a similar reaction was taking place at the negative electrode. Hydrogen gas ($H_2\uparrow$) was being formed. According to your equation and what you observed in the electrolysis tubes, you may assume that twice as many molecules of hydrogen gas were formed as were molecules of oxygen gas.

From your observations, and from the volumes of gases you determined by balancing the equation, you can now say that a glowing splint bursting into flame is a test for one of these gases. Which one? What is the test for the other gas?

You have just done four things in carrying out this activity: (1) made observations (2) drawn conclusions (3) balanced an equation (4) determined the tests for two common gases. You must realize that you could not have known which gas was which without both observation of results and the inferences that you were able to draw about the gases from a study of the balanced equation. Scientists must use mathematical and chemical equations often to find answers to science problems.



Producing a Gas From an Acid

You may have wondered why, in the explanation for balancing an equation, $H_2O \rightarrow H + O$ was written down first. It was already known that these products were gases with two-atom molecules. Watch for the reason in the material that follows.

> **Place some pieces of metallic zinc in a beaker and cover the metal with some dilute hydrochloric acid. Place test tube over zinc, as in diagram.**
>
> **After some gas has been collected in the test tube, test it to see if it acts like hydrogn or oxygen.**

Now that you have observed that it reacts like hydrogen gas, try to write and balance the equation for what appears to be a single replacement.

$$Zn + HCl \longrightarrow H + ZnCl$$

Again you have written only one of each of the atoms in the products. It has been found that this makes it easier to write the proper molecular formula in the equation in the next step. The zinc and acid formulas are correct, as they were known at the start. H_2 must be written for the molecule of hydrogen gas. Now look up the valence of zinc and chlorine on page 37 in order to check the number of atoms of each in the molecule of zinc chloride. Do you get $ZnCl_2$ as the proper formula? If so, you can now write:

$$Zn + HCl \longrightarrow H_2\uparrow + ZnCl_2$$

If you follow the same reasoning as before in balancing, you will get

$$Zn + 2HCl \longrightarrow H_2\uparrow + ZnCl_2$$

Finally, double check the equation to be sure it is balanced. It is.

Can you balance this equation? Its molecular formulas are correct.

$$Hg + O_2 \longrightarrow HgO$$

SUMMARY

It is possible to write a chemical equation that represents the way molecules of substances seem to behave in a chemical reaction. The products of such a reaction must be made up of the same number and the same kinds of atoms as the reacting substances. To be sure that they are, it is necessary to balance carefully every equation. These are the steps.

1. Write the proper molecular formulas for all molecules involved. Do not change these later.

2. Check to make sure that the same number of each kind of atom appears on both sides of the equation.

3. If the same number does not appear, increase the number of molecules involved and check again.

4. Make a final double check after the last change has been made.

Activities

A. *Testing Yourself*

In the proper place on your answer sheet, write the letter of the ending that best completes each of the following statements.

1. Mg^{++} is (a) a metal atom (b) a nonmetallic ion (c) an ion of magnesium (d) a valence of 2.

2. The symbol written first in a molecular formula is usually the (a) metal (b) nonmetal (c) radical (d) gas.

3. H—O—H is (a) an empirical formula (b) a structural formula (c) an equation (d) a reaction.

4. $2\,Na + 2H(OH) \rightarrow 2Na(OH) + H_2\uparrow$ represents (a) synthesis (b) analysis (c) single replacement (d) double replacement.

5. The equation in number 4 is (a) a gas (b) balanced (c) radicalized (d) unbalanced.

6. One of the reacting substances in a neutralization reaction is always (a) an acid (b) a salt (c) water (d) a gas.

7. You must be sure that molecular formulas are properly written before you can (a) study chemistry (b) learn the symbols for the elements (c) tell analysis from synthesis (d) balance a chemical equation.

8. A gas that causes a glowing splint to burst into flame is (a) chlorine (b) carbon dioxide (c) hydrogen (d) oxygen.

9. One of the products of a chemical reaction always is (a) a gas (b) a salt (c) a molecule (d) water.

10. The valence of nitrogen in "laughing gas" (N_2O,) is (a) +1 (b) +2 (c) +3 (d) +4.

11. You have not finished balancing the equation of a chemical reaction until you have (a) written the proper molecular formulas (b) counted atoms on both sides (c) double checked the count (d) shown it to your teacher.

B. *Working With Reactions*

Write the numbers 1 to 5 on your answer sheet. After each number write one of the following letters to indicate the type of reaction each formula represents: S (Synthesis), A (Analysis), SR (Single Replacement), DR (Double Replacement). Then complete each equation and balance. All molecular formulas given are correct.

1. $S + O_2 \rightarrow$ (Valence of S is +4.)
2. $Na_2(SO_4) + BaCl_2 \rightarrow Ba(SO_4) +$
3. $KClO_3 \rightarrow KCl + O_2\uparrow$
4. $C + SnO_2 \rightarrow Sn + CO\uparrow$
5. $WO_3 + H_2 \rightarrow H_2O + W$

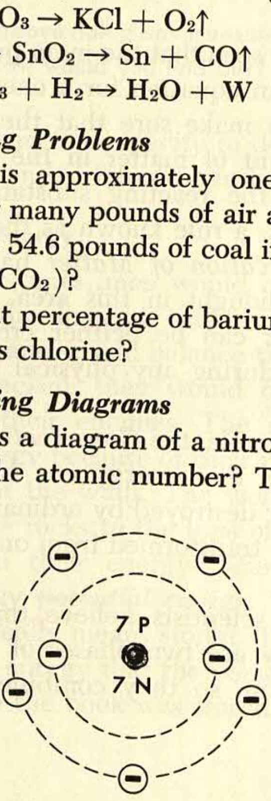
C. *Solving Problems*

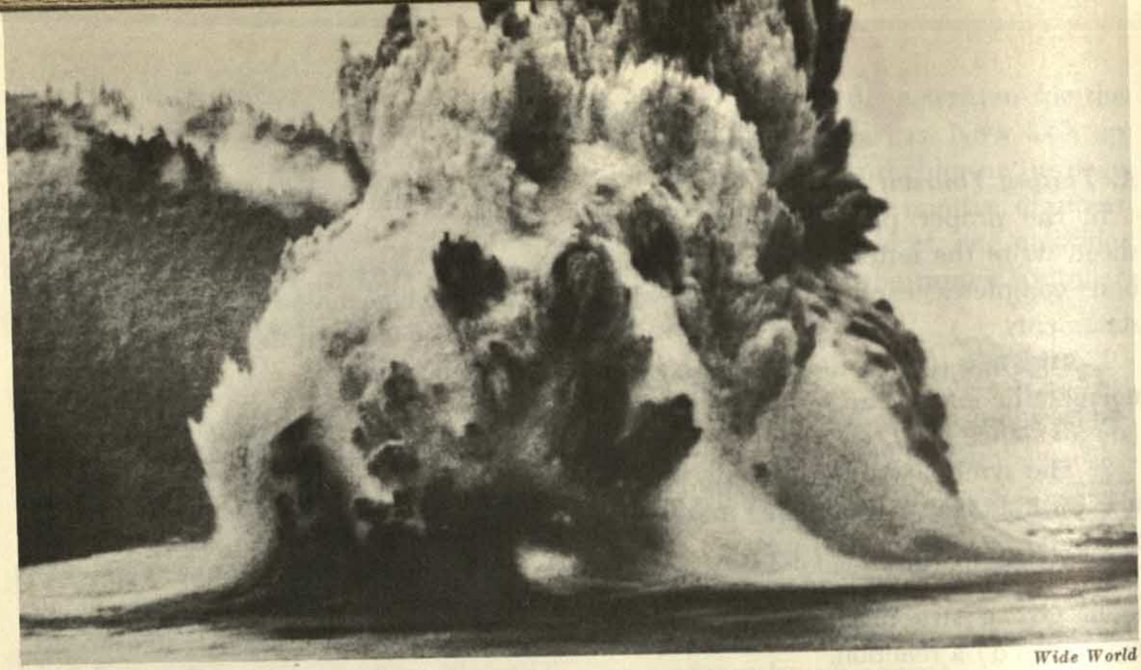
1. Air is approximately one-fifth oxygen. How many pounds of air are needed to change 54.6 pounds of coal into carbon dioxide (CO_2)?

2. What percentage of barium chloride ($BaCl_2$) is chlorine?

D. *Studying Diagrams*

Below is a diagram of a nitrogen atom. What is the atomic number? The atomic weight?





Wide World

An explosion is a chemical reaction which releases a good deal of energy at a rapid rate.

PROBLEM 4: HOW DOES ENERGY ENTER INTO CHEMICAL REACTIONS?

You have seen that the main purpose of balancing an equation for a chemical reaction is to make sure that there is the same amount of matter in the products as was in the reacting substances. For many years, a rule known as the *Law of the Conservation of Matter* has guided scientific thought in this area. It states that matter can be neither created nor destroyed during any physical or chemical change.

A similar rule, the *Conservation of Energy*, states that energy can be neither created nor destroyed by ordinary means, but merely transformed from one form to another.

Today's scientists believe that matter and energy are two phases of the same phenomenon, so they combine the two conservation laws and speak of the *Conservation of Mass-Energy*. You will learn more about their reasons for doing this as you continue with this problem.

ENERGY TO DO WORK

Energy is defined as the capacity to do work. Work, however, is a word of many meanings in itself.

Scientific Meaning of Work

Have you ever thought what a person really means when he says that he has worked hard? If a person has been active and feels tired, he may say that he has worked hard, but has he? Many of you use the word work but think little about its exact meaning.

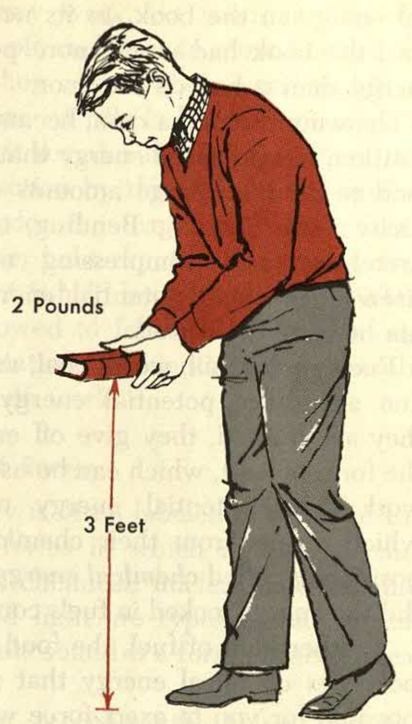
Scientists discovered that they could measure work to find out how much was actually done. In order to measure work, they had to define it so that it would mean the same thing to every one. Scientists agree that work results when a force acts through a distance. Since the amount of force and the distance through which it acts can be measured accurately, work can also be measured and expressed in specific units.

Expenditure of Energy

There are two conditions which must be met if work is to be done according to its scientific definition. First, a force must be exerted. Second, a force must move through a distance. If either condition is not present in a situation, work, in a scientific sense, is not being done.

Suppose, for example, some one pushed and pushed upon an overturned automobile until he was completely exhausted. He did not, however, move the automobile. In the scientific sense, no work was done because the force exerted by his pushing did not move through any distance. By pushing until he was exhausted, the person merely used up his capacity to do work. It is entirely possible for a person to use up his energy and yet accomplish no work.

Lifting a book from the floor is work because motion is produced in the direction of the force exerted. The force exerted upward is equal to the weight of the book, say, 2 pounds. Remember that weight is a measure of the pull of the earth's gravity straight down. In lifting a book 3 feet, a person is doing 6 foot-pounds of work (3 feet × 2 pounds). Because he had the capacity to do this, you say he expended 6 foot-pounds of energy.



Is the man above doing any measurable amount of work? How would you find out?

Potential Energy

In early times, men would carry large rocks to the tops of walls surrounding their forts and would balance them there. When attacked, they would drop these rocks on their enemies. The rocks possessed energy because of their position on the tops of the walls. The work done in moving the rocks to the tops of the walls gave them their energy. Scientists call such energy ***potential energy.*** The word potential really means stored. The 6 foot-pounds of energy that the person used in picking up the book was stored as potential energy in the book. In its new position, the book had much more potential energy than it had on the floor.

The water behind a dam, because of its position, has potential energy that can be used to generate large amounts of electricity (see Unit 5). Bending, twisting, stretching, and compressing materials often gives them potential energy that can be used to do work.

Fuels such as oil, wood, coal, and gasoline also have potential energy. When they are burned, they give off energy in the form of heat, which can be used to do work. The potential energy of fuels, which results from their chemical composition, is called ***chemical energy.*** Where did the energy locked in fuels come from?

Another kind of fuel, the food you eat, possesses chemical energy that makes it possible for you to exert force with your muscles and thus to do work.

Atomic Energy

In the early morning hours of July 16, 1945, a new type of bomb was exploded in an isolated part of a desert in New Mexico. A new source of potential energy had been tapped. This energy, locked deep within the nuclei of atoms, is called ***atomic energy.***

Atomic energy is a form of potential energy that is in all atoms because of their internal structure. Scientists have learned how to release this energy from the atoms of the elements uranium, thorium, plutonium, and hydrogen.

Kinetic Energy

There is another type of energy which scientists call ***kinetic energy.*** Kinetic energy refers to the ability of an object to do work because it is moving. A bullet in flight possesses kinetic energy because it does work on any object it happens to strike. The kinetic energy of a moving automobile is responsible for the resulting damage when it hits something. The kinetic energy of moving water turns water wheels and water turbines used to do work.

The ***kinetic theory of matter*** maintains that molecules of matter are in continual motion. This theory states that the moving molecules of one pound of water, for example, move more freely when the water is a gas than when it is a liquid, and least freely when it is a solid.

Comparison of the temperatures (the average kinetic energy of all the molecules) of steam, of water, and of ice indicates that the total kinetic energy of the molecules of a pound of water is least in the solid state and greatest in the gaseous. Thus, steam molecules are considered to be moving with greater energy and to have more ability to do work than water molecules.

Work From Heat

Blow up a balloon to almost full size. Did the rubber move? Do you think work was done? Aim the mouth of the balloon at some pieces of paper on a table and let the air escape. Is work done by the air on the paper?

Partially fill a balloon with air and measure its size. Hold it in a pan over a heat source to add kinetic energy of heat to the molecules of air inside the balloon. Can heat energy be changed into work? What did you observe that supports your answer?

Heat Energy From Work

Rub your hands together. Work is done because you are exerting a force which is acting through a distance. Observe that your hands are warmed in the process. Apparently heat results from using energy to do work in this case. Sound energy also results. Listen as you rub.

TRANSFORMATION OF ENERGY

Ancient man lived in a world filled with potential energy. Coal, oil, and water were present in his world, as well as atoms of uranium. These sources of energy were of little value to him because he did not know how to convert them into kinetic energy that could do work for him. As man learned how to transform potential into kinetic energy, modern civilization developed.

Relationship of Potential To Kinetic Energy

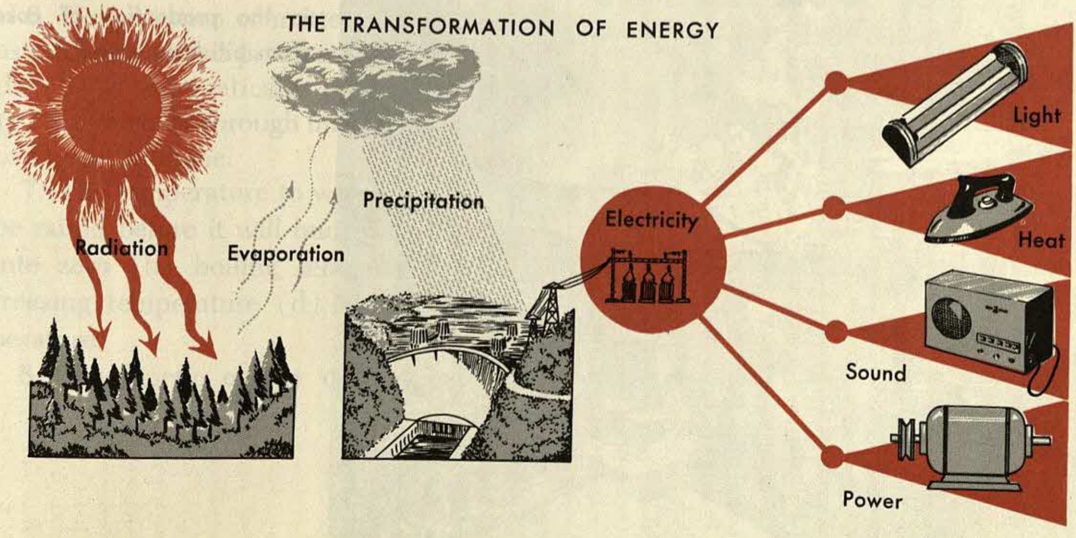
Potential energy must be changed to kinetic energy before it can be used to do work. The rocks raised to the walls of the fort can stay there indefinitely without doing any work. As soon as they are pushed off and start to move toward the earth, they can do their work by hitting the enemy. A rifle bullet does no work so long as it remains in the gun. When it is given motion by the force of the exploding powder, it is capable of doing work. The water behind a dam does no work so long as it is held back by the dam. When it is allowed to fall swiftly down to the power station, its kinetic energy can be used to do work.

Forms of Energy

Energy is often labeled in terms of the various forms in which it appears: mechanical, chemical, nuclear, and radiant. Heat and light are types of radiant energy, while sound is a form of mechanical energy.

Energy is constantly being changed from one form to another in nature and by man. This process of change is known as the ***transformation of energy.*** A series of energy transformations is shown in the diagram below. Watch for evidences of energy in its different forms and types and for its transformation, as you study science.

THE TRANSFORMATION OF ENERGY



Chemical Energy

In the electrolysis of water, page 37, no reaction would be possible without electrical energy. On page 44, it was stated that heat was needed to synthesize zinc sulfide from its elements.

Nitroglycerine will explode if the energy of mechanical shock is applied to it.

The reversible reaction represented by $H_2CO_3 \rightleftarrows CO_2 + H_2O$ will go to the right when heated and will go to the left when cooled. The burning of fuels to supply heat energy can be stopped if the molecules of fuel have their energy level reduced below that average kinetic energy known as the ***kindling temperature.*** Kindling temperature is the lowest temperature at which a substance starts to burn.

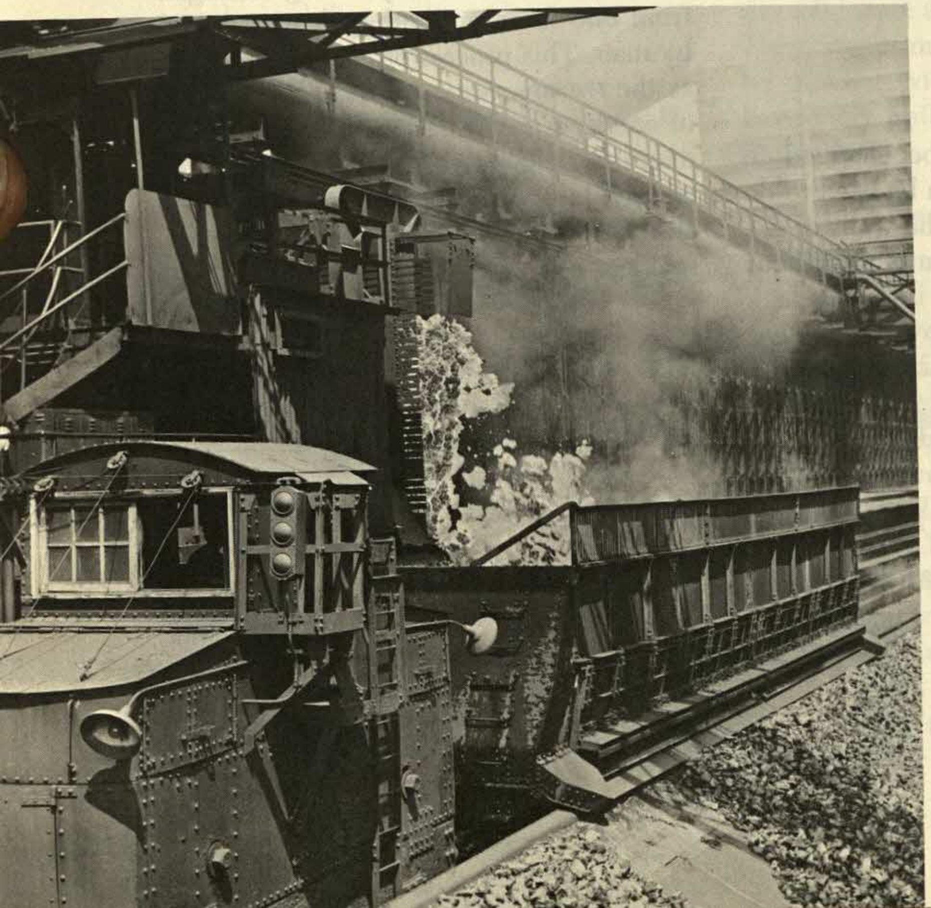
Chemical reactions that absorb heat energy are called ***endothermic reactions,*** while those that give off heat energy are termed ***exothermic reactions.***

Accidents in chemical laboratories can be prevented by keeping in mind the type of heat exchange involved.

SUMMARY

Energy is the ability to do work. Work involves the action of a force through a distance. Energy can be stored in many forms as potential energy. The energy of a moving object is called kinetic energy. The kinetic energy of man comes from the stored chemical energy in the food he eats. There is an energy change involved in every chemical reaction. Energy has to be supplied to make some reactions take place. In fires or explosions, large amounts of energy are given off.

U. S. Steel



A great deal of heat is used in the production of coke from bituminous coal.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. The amount of work required to move an object can be determined if you know (a) the distance the object is moved (b) the force required to move the object (c) the speed at which the object moves (d) the force and the distance through which it will be moved.

2. A rock balanced on top of a mountain possesses usable energy in the form of (a) potential energy (b) kinetic energy (c) chemical energy (d) atomic energy.

3. Energy is thought of as the (a) number of molecules a substance contains (b) speed of a moving object (c) capacity to do work (d) weight of an object.

4. An arrow shot from a bow possesses usable energy in the form of (a) potential energy (b) kinetic energy (c) chemical energy (d) atomic energy.

5. Changing energy from one form to another is known as (a) conservation of energy (b) transformation of energy (c) capacity to do work (d) release of energy.

6. Conservation of matter or of energy as discussed in this problem (a) is hard to do (b) is automatically done in nature (c) is done only through man's efforts (d) can never be done.

7. The temperature to which fuel must be raised before it will burn is (a) absolute zero (b) boiling temperature (c) freezing temperature (d) kindling temperature.

8. The kinetic energy of man comes from (a) muscles (b) food (c) water (d) brain.

9. Energy doing work is called (a) kinetic (b) potential (c) residual (d) basic.

10. When a chemical reaction gives off energy, the reaction is known as (a) potential (b) kinetic (c) conservative (d) exothermic.

B. Recognizing Relationships

Following the generalization below is a list of statements which may, or may not, illustrate the generalization. On your answer sheet write the letters of the statements which illustrate the generalization.

GENERALIZATION: Transformation of energy enables you to utilize the sources of potential energy.

a. Energy is the capacity to do work.

b. An automobile uses gasoline for fuel.

c. The force of falling water often turns generators that produce electricity.

d. Green plants use sunlight in producing food.

e. Kinetic energy is the ability of an object to do work because it is moving.

f. Some clocks have numbers that glow in the dark.

g. Space probers use solid fuels to overcome the effect of the earth's gravity.

h. As heat is added to a substance, its molecules move faster.

i. A force must be exerted before work can be done.

j. Much of the energy man obtains from the food he eats is changed to heat.

k. Digestion serves to break food molecules into smaller molecules.

l. Foods are oxidized in the body and release heat.

Brookhaven National Laboratory

PROBLEM 5: HOW IS ENERGY OBTAINED FROM MATTER?

In the two previous problems you learned that it is possible to get energy from exothermic chemical reactions. You also learned that doing work on matter, such as lifting a stone, may add potential energy to it. This potential energy can be released later as kinetic energy.

In this problem you will study ways that have been devised to convert matter directly into energy. The transformation of matter into energy is made possible through ***nuclear reactions.*** These are not ordinary chemical reactions in the sense that they take place between the planetary electrons of atoms. They are reactions between the particles making up the nuclei of atoms. Atomic energy is a form of potential energy that is possessed by all atoms.

DAWN OF THE ATOMIC AGE

Early in the twentieth century, newspapers published stories about the tremendous amounts of energy locked within the atom. If this energy could be used in some way, there would be enough of it in a cup of water to drive a large liner across the Atlantic Ocean and back. Or a container the size of a fountain pen could contain all the fuel needed to run an automobile for a lifetime.

Einstein's Work

The newspaper stories were based on a theory stated in 1905 by Albert Einstein, an amateur mathematician and civil service clerk in Switzerland. Einstein believed that all matter in the universe was somewhat like condensed energy and that all energy was somewhat like diluted matter. In other words, matter and energy were essentially the same thing in different forms.

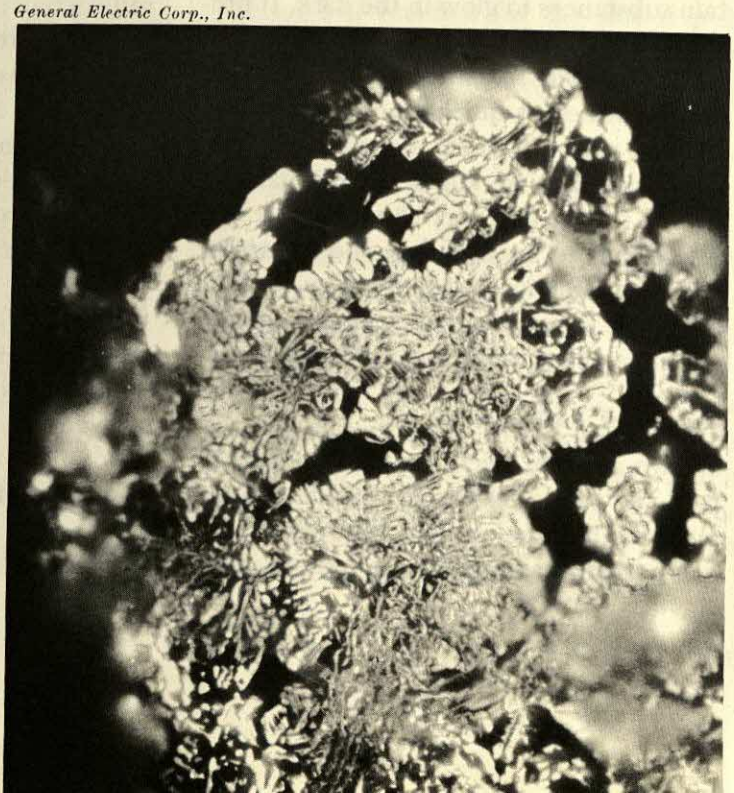
If this hypothesis were true, then locked deep within the atom must be a tremendous amount of energy that could be obtained by converting some of the matter of the atom into energy.

Calculations based upon Einstein's theory revealed that if 2.2 pounds of matter could be changed into energy, it would produce 25 billion kilowatt-hours of electricity. The burning of 2.2 pounds of coal produces only 8.5 kilowatt-hours. This potential energy locked in atoms is called atomic energy in order to distinguish it from the energy of the molecules of fuel called chemical energy.

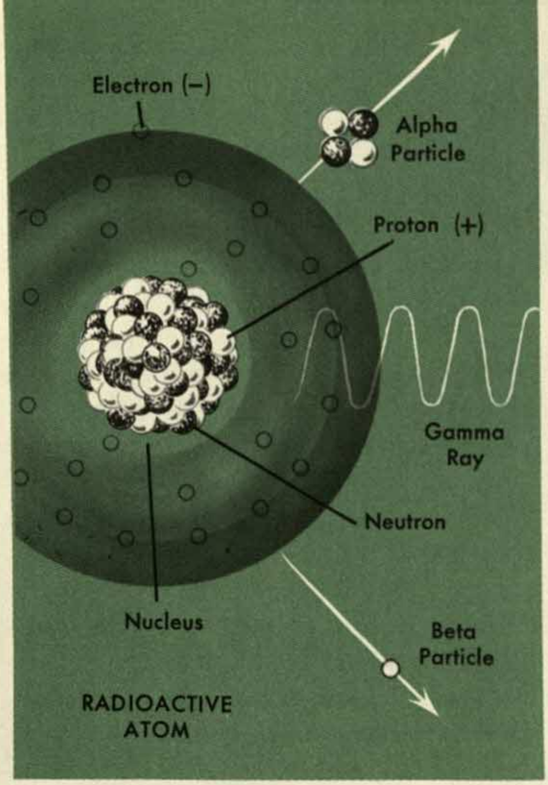
Development of Atomic Energy

In 1896, Henri Becquerel (on-REE be-KREL), a French scientist, accidentally discovered that a piece of uranium ore would darken an unexposed photographic plate when placed near it. Further investigation revealed that a type of uranium ore derived from the mineral ***pitchblende*** was especially powerful in its ability to affect photographic plates. Becquerel did not have time to pursue his findings further. Instead, he suggested that Pierre Curie and his wife Marie Curie (kyoo-REE) investigate this problem. After a tremendous amount of work, the Curies finally obtained half a teaspoonful of a very powerful substance from about eight tons of uranium ore. They named this new element ***radium.***

General Electric Corp., Inc.



Effect of a polished piece of uranium-bearing rock on photographic plate is shown at right. Autoradiograph required twelve-hour exposure.



Properties of Radium

Radium was found to have a great many unusual properties. It caused certain substances to glow in the dark. It produced enough heat to raise its own weight in water from freezing to boiling in an hour. Because it quickly acted on photographic plates, it made pictures similar to x-ray pictures. It killed microörganisms placed near it in a very short time. It was also found to be useful in the treatment of cancer. Radium was also very unusual in that it seemed to be supplying energy continuously without ever wearing out.

Nature of Radioactivity

Two English scientists, Ernest Rutherford and Frederick Soddy, decided to find out whether they could determine what was actually taking place in radium. They finally discovered, along with other scientists working on this problem, that the ***radiations*** (rays) emitted by radium are complex and consist of two types of particles and one type of ray. These radiations, called ***alpha particles, beta particles,*** and ***gamma rays,*** are diagrammed at left. The process radium undergoes naturally to enable it to emit these three types of radiation is called ***radioactivity.***

Further study revealed that, as radium releases its rays, it disintegrates and changes from one element to another, until finally it loses its radioactivity and becomes the stable element lead.

Since an atom of lead weighs less than an atom of radium, it was assumed that some of the matter of the radium atom changes into energy. During this process, a tremendous amount of heat is released. However, the change from radium to lead is so slow that the heat is not produced fast enough to be of any practical value.

There can be only one explanation for radioactivity. The element radium radiates its matter away in the form of alpha and beta particles and gamma rays. Radioactivity is a natural process in which atomic energy is released. If scientists could duplicate this process, they could tap the tremendous store of potential atomic energy for their own use.

Symbols for Atomic Particles

The chemical shorthand which uses symbols, formulas, and equations had proved so valuable to the chemist in studying ordinary reactions that a similar shorthand for nuclear reactions was devised. The table on page 59 gives the meaning of some of these symbols.

Some Symbols Used in Nuclear Reactions

neutron	${}_0n^1$ (or n)
electron	${}_{-1}e^0$
proton	${}_1H^1$ (or p)
energy given off	$+ Q$
energy taken on	$- Q$

deuteron	${}_1H^2$
triton	${}_1H^3$
alpha particle	${}_2He^4$ or α
beta particle	${}_{-1}e^0$ or β
gamma ray	γ

Writing Nuclear Equations

Ordinary chemical reactions involve only the planetary electrons. Nuclear reactions, on the other hand, involve only the nuclei of atoms. In addition to the standard symbols for the parts of a nucleus, a standard form is used for the symbol of the nucleus of any element.

An oxygen nucleus, for example, is represented by either ${}_8O^{16}$ or O^{16}. An oxygen-16 atom has eight planetary electrons in its shells and a nucleus containing eight protons and eight neutrons.

The atomic number (Z) of an element, which is the number of protons in the nucleus of an atom, is written as a subscript before the chemical symbol of the element. Oxygen, for example, has an atomic number of eight.

The total number of protons and neutrons, called the ***mass number*** (A), is written as an exponent for the symbol. Oxygen has an atomic mass of sixteen. The mass number is the nearest whole number to the atom's atomic mass.

The ***neutron number*** (N) can be found only by subtracting the atomic number from the mass number as follows:

$$A - Z = N$$

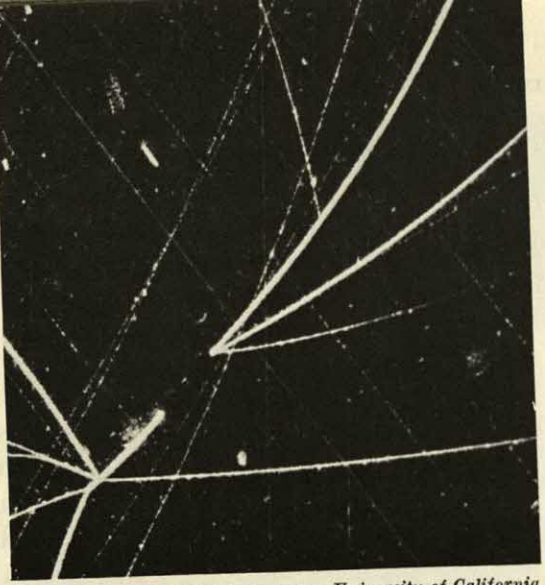
A different atom of oxygen, which has eight protons and nine neutrons would have as its nuclear symbol ${}_8O^{17}$.

Atoms of the same element, but with different mass numbers, are known as ***isotopes.*** The only difference between isotopes is the number of neutrons in their nuclei. The number of protons and electrons is the same. Ordinary hydrogen or ***protium*** (PROH-ti-um), ***deuterium*** (dyoo-TEER-ee-um), and ***tritium*** (TRIT-ih-um) are isotopes of hydrogen. Note again the symbols used in nuclear reactions. The nucleus of the protium atom is a proton (${}_1H^1$); of deuterium is ***deuteron*** (${}_1H^2$); of tritium, a ***triton*** (${}_1H^3$). An alpha particle, ${}_2He^4$, is actually the nucleus of a helium atom.

When you use these symbols to write the nuclear reaction for the first step in the radioactive disintegration of radium 226, you get the following nuclear equation:

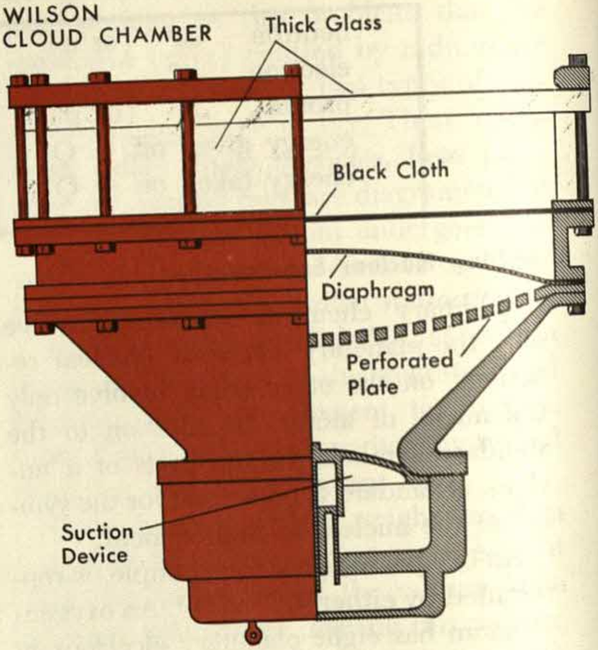
$$\underset{\text{radium}}{{}_{88}Ra^{226}} \longrightarrow \underset{\text{radon}}{{}_{86}Rn^{222}} + \underset{\substack{\text{alpha}\\ \text{particle}}}{{}_2He^4} + \underset{\text{energy}}{Q}$$

Note that as the radium atom decays, it emits an alpha particle, ${}_2He^4$, and disintegrates into an atom of radon, which has fewer protons and a lower mass number. Notice, also, that the totals of the mass numbers (exponents) on each side of the equation balance, as do the totals of the atomic numbers (subscripts). Since energy was given off, it is indicated in the equation by the addition of "Q."



Courtesy Radiation Laboratory, University of California

Above are tracks of particles from two carbon and oxygen atoms, which broke apart when struck by high-energy neutrons in a Wilson cloud chamber used for nuclear research.



Transmutation of Elements

In 1919, Lord Rutherford suggested that it might be possible to change one element into another by bombarding its atoms with the alpha particles given off by radium. To test his idea, Rutherford bombarded the atoms of nitrogen gas with alpha particles from radium. By this process he changed nitrogen into an isotope of oxygen and also obtained a high-speed particle, which was a hydrogen nucleus (proton).

The change of one element into another is called ***transmutation.*** Lord Rutherford's experiment was recognized as the first achievement of transmutation by man. The equation for this experiment is as follows:

$$\underset{\text{nitrogen}}{{}_{7}\text{N}^{14}} + \underset{\text{alpha particle}}{{}_{2}\text{He}^{4}} \longrightarrow \underset{\text{oxygen isotope}}{{}_{8}\text{O}^{17}} + \underset{\text{proton}}{{}_{1}\text{H}^{1}} + \underset{\text{energy}}{\text{Q}}$$

Detecting Radioactivity

For the first quarter of this century, electrons and protons were thought to be the only parts of the atom.

Since 1912, vapor trails of charged particles have been studied in the ***Wilson cloud chamber.*** The cloud chamber is an instrument, or enclosure, invented by the English physicist, C. T. R. Wilson, of Cambridge University. On page 71, you can find out how to construct a cloud chamber. Because it proved so valuable in tracing the paths left by nuclear particles and in other research projects, Wilson was awarded the Nobel prize in physics in 1927. Paths of an electron and of a proton in such a chamber are shown on this page, along with tracks of $_{8}O^{17}$ and alpha tracks. No track has ever been made in a cloud chamber by a neutron. Can you tell why?

Discovery of Neutrons

In 1932, an English scientist, James C. Chadwick, discovered the neutron. He did this by bombarding atoms of the metal beryllium (Be) with alpha particles. The equation represents the result.

$$_4Be^9 + _2He^4 \longrightarrow _6C^{13} \longrightarrow _6C^{12} + _0n^1$$

Beryllium 9 was changed to radioactive carbon 13. This, in turn, changed to carbon 12 with the release of a neutron which carried no charge whatever.

PARTICLE ACCELERATORS

Rutherford's experiment with alpha particles proved that one element could be changed into another. However, he was able to transmute only the lighter elements—those having small atomic masses. This was because his bombarding particles from the alpha ray of radium were themselves so light that their kinetic energy, or motion, was small. It has since been found that the kinetic energy of an object is increased both by an increase in the mass of the object and by an increase in its speed.

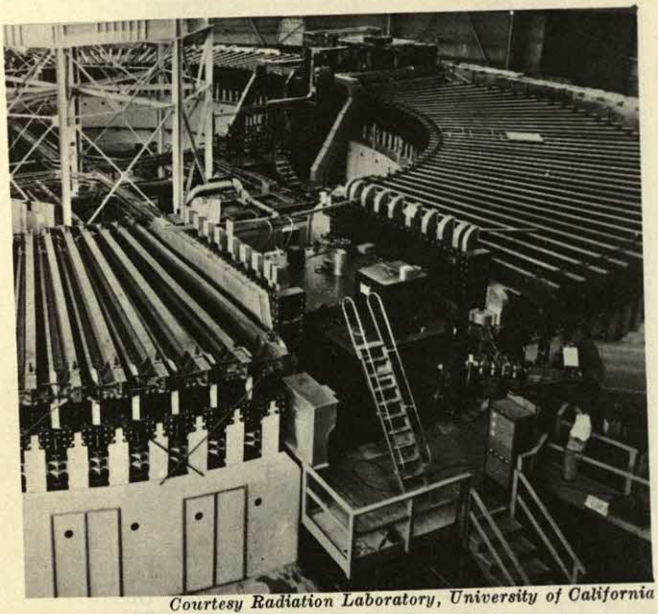
Increasing the speed of an object is called ***acceleration.*** It was thought to be impossible to increase the mass of atomic particles. Hence scientists concentrated on increasing their speed. With faster moving particles, they reasoned, they might obtain enough kinetic energy to smash the atom and cause transmutation of heavier elements. Several types of machine, called ***particle accelerators,*** were designed to activate nuclear particles to high energies. A description of some accelerators now in use follows.

Van de Graaff Generator

The Van de Graaff electrostatic generator, invented in 1931, was one of the first special machines built for the purpose of accelerating particles. Static electricity, such as was produced in the demonstration described on page 32, is used as the energy to accelerate particles. Research models have been built to develop energies up to 10 or 15 ***Mev.*** A Mev is a unit of energy equal to a million ***electron volts. Bev*** represents an energy unit of a billion electron volts. An electron volt is equal to 1.60×10^{-12} ergs. An ***erg*** is a unit of work or energy. The energy of this type of accelerator is released in a short space of time as a sudden discharge. That is, the particle gets one accelerating burst of energy.

Linear Accelerators

Linear accelerators accelerate the particles in a straight line by a series of electrostatic kicks. You can set a swing in motion with one little push and increase its swinging motion with each successive push if you give it at just the proper time. Similarly, the successive applications of force to the particles can cause them to reach speeds at which their energies may be as high as 1,000 Mev (1,000 Mev = 1 Bev). The disadvantage of this accelerator is that, at the end of one trip through it, the particle has reached the highest possible energy level it can achieve in this machine. The energy of the particle is still relatively low. If higher energies than can be reached in a linear accelerator are needed, then it becomes necessary to use a longer machine to achieve the results required.



Courtesy Radiation Laboratory, University of California

Bevatron accelerates protons' energy level.

Circular (Rotary) Accelerators

In the ***cyclotron*** (SY-kluh-tron), developed by the American scientist Dr. E. O. Lawrence, the particle can be whirled around repeatedly. It was designed to overcome certain of the limitations of the linear accelerator. However, because of size limitations, energies of only 30 Mev were obtainable. It was also found that the particle increased in mass at the high speeds possible. Thus it was proved that energy could be changed into matter as Einstein had claimed.

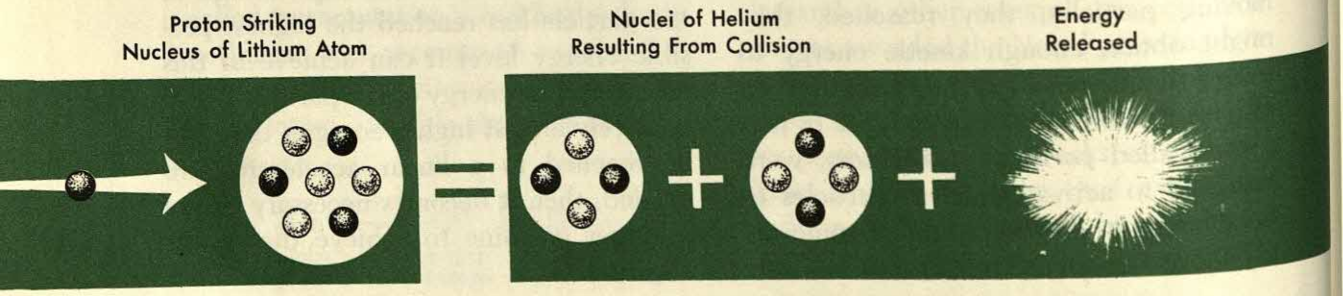
The ***synchro*** (SING-kroh)***-cyclotron*** was developed to take advantage of the change in mass of the accelerating particle and to make allowances for it. Machines of this type could develop energies up to 750 Mev. Through the design and construction of the ***proton-synchrotron,*** the ***betatron,*** and the development of the strong-focussing principle, energies as high as 50 to 100 Bev are now theoretically possible.

Splitting the Atom

These high-energy particles are useful mainly in the bombardment of atomic nuclei and not as sources of atomic energy. In 1932, two English scientists, J. D. Cockroft and E. T. S. Walton, bombarded atoms of the metal lithium with high-speed protons (hydrogen nuclei). The lithium atom was broken into two parts, each part being the nucleus of a helium atom. Furthermore, energy was released when the lithium atom was broken apart. The reaction is represented by the following equation:

$$\begin{array}{ccccccccc} {}_{3}\mathrm{Li}^{7} & + & {}_{1}\mathrm{H}^{1} & \longrightarrow & {}_{2}\mathrm{He}^{4} & + & {}_{2}\mathrm{He}^{4} & + & Q \\ 7.01822 & & 1.00815 & & 4.00388 & & 4.00388 & & 0.01861 \end{array}$$

The numbers under the above equation are the ***atomic mass units (amu)*** of the isotopes. The term amu is used in atomic



and nuclear physics to indicate that a unit of mass equals one-twelfth of the mass of a carbon isotope.

Investigation showed that the total mass of the two helium nuclei that were yielded in the experiment did not equal that of the lithium atom and the proton from which they came. From the atomic mass units given, it seemed as if 0.01861 amu were converted into energy. When 0.01861 was substituted for m in Einstein's famous formula, $E = mc^2$, the amount of energy was the same as that obtained in the actual experiment. There was no longer any question that matter could be changed into energy.

Splitting Uranium Atoms

Enrico Fermi, an Italian scientist, believed that the recently discovered neutrons might make good atomic bullets. In 1934, he began a series of experiments in which he bombarded uranium atoms with neutrons.

Up to this time, one of the biggest problems had been to hit the nuclei of the atoms being bombarded. There was so much space in the atom that the atomic bullets rarely hit a nucleus during the bombardment.

Fermi discovered that, if the neutrons were slowed down, a much higher percentage of hits could be achieved. By bombarding uranium atoms with slow neutrons, he succeeded in making a new element not then found in nature. The new element was called ***neptunium*** (nep-TYOO-nee-um) ${}_{93}Np^{239}$. The equation for this nuclear reaction is as follows:

$${}_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239} \longrightarrow {}_{93}Np^{239} + {}_{-1}e^{0}$$

In 1939, two German chemists, Otto Hahn and Fritz Strassmann, studied the effect on uranium atoms of bombardment by neutrons. The following year two Austrian physicists, Lise Meitner and Otto R. Frisch, explained this reaction as the splitting of the nucleus of a heavy atom into nuclei of two atoms of medium size. They named the process ***nuclear fission.***

By bombarding uranium with neutrons, they produced an atomic explosion on a small scale. The results of this work were made available to scientists all over the world. For the first time, it seemed possible to use atomic energy.

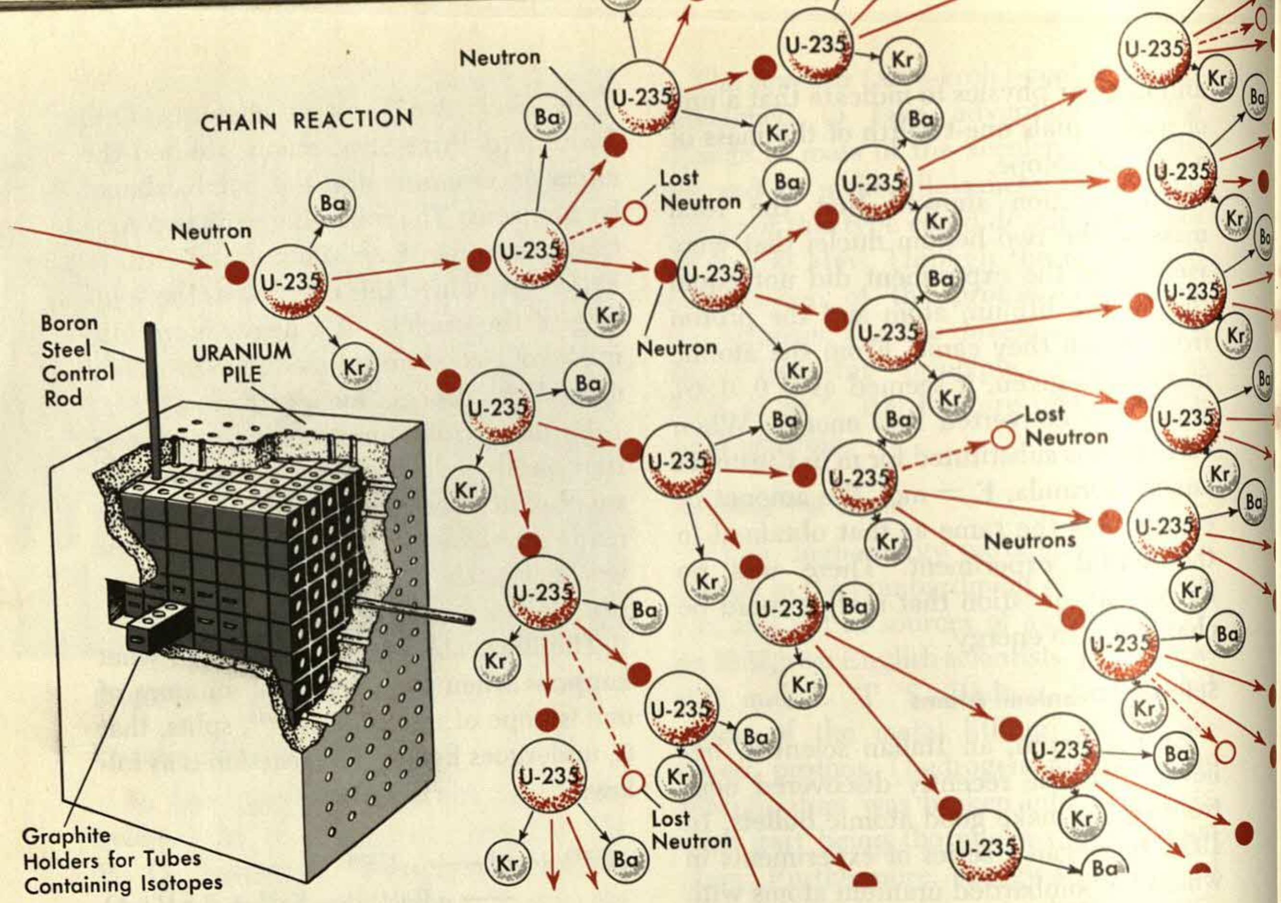
The illustration on page 64 shows what happens when the nucleus of an atom of one isotope of uranium, ${}_{92}U^{235}$, splits, that is, undergoes fission. The reaction is as follows:

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{92}U^{236}$$
$$\longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_{0}n^{1} + Q$$

HEAT ENERGY FROM MATTER

It occurred to Dr. Fermi that the extra neutrons expelled by a uranium atom when it underwent fission might be used to break other atoms. These neutrons could, in turn, be used to break still others. This process could continue as long as a sufficient number of uranium atoms were present. This process is called a ***chain reaction.***

Something like a chain reaction is responsible for burning of ordinary fuels once they reach kindling temperature. The heat resulting from the oxidation of some of the molecules excites other molecules to oxidize. The oxidation thus main-



A chain reaction, or nuclear fission, results from the bombardment of atoms of U-235 with neutrons.

tains itself until the fuel is gone. A similar chain reaction with uranium would make it possible to use uranium as a source of energy.

The Atomic Pile and Fission

A device had to be built to test Fermi's idea that a chain reaction could be used to obtain energy from uranium. The first successful device for this purpose was constructed in 1942 at the University of Chicago under Dr. Fermi's supervision. This device, originally called an ***atomic pile,*** consisted of pure uranium and uranium oxide embedded in blocks of graphite. The function of the graphite was to slow down the neutrons, because it had been found that slow-moving neutrons brought about fission more effectively than fast-moving ones.

Strips of cadmium metal were also placed in the pile to absorb some of the neutrons and thus control the rate at which the slow-moving neutrons split atoms in producing chain reactions.

Instruments were installed to measure the amount of energy that would be released by the pile once it was started. When all was in readiness, the cadmium rods were partially withdrawn from the pile. As this was done, the instruments showed that there was an increase in energy from the pile. It was apparent that a chain reaction could be started and controlled in such an atomic pile. For the first time in history, atomic energy had been tapped so that its rate of release was under man's control.

Atomic Energy From Fusion

The production of atomic energy so far described results from nuclear fission. Nuclear fission of atoms of heavy elements produces atoms of light ones, large amounts of energy, and additional nuclear particles.

It is also possible to release atomic energy by forcing the nuclei of hydrogen atoms to combine. This process is called ***nuclear fusion.***

Scientists believe that several fusion reactions can be used to produce useful power, provided that a temperature of 350,000,000° C can be reached. The most promising are listed below. Can you name each of these symbols?

$$
\begin{aligned}
{}_1\mathrm{H}^2 + {}_1\mathrm{H}^2 &\longrightarrow {}_2\mathrm{He}^3 + {}_0\mathrm{n}^1 + \mathrm{Q}\ (3.25\ \mathrm{Mev})\\
{}_1\mathrm{H}^2 + {}_1\mathrm{H}^2 &\longrightarrow {}_1\mathrm{H}^3 + {}_1\mathrm{H}^1 + \mathrm{Q}\ (4.0\ \mathrm{Mev})\\
{}_1\mathrm{H}^2 + {}_1\mathrm{H}^3 &\longrightarrow {}_2\mathrm{He}^4 + {}_0\mathrm{n}^1 + \mathrm{Q}\ (17.3\ \mathrm{Mev})\\
{}_1\mathrm{H}^2 + {}_2\mathrm{He}^3 &\longrightarrow {}_2\mathrm{He}^4 + {}_1\mathrm{H}^1 + \mathrm{Q}\ (18.3\ \mathrm{Mev})
\end{aligned}
$$

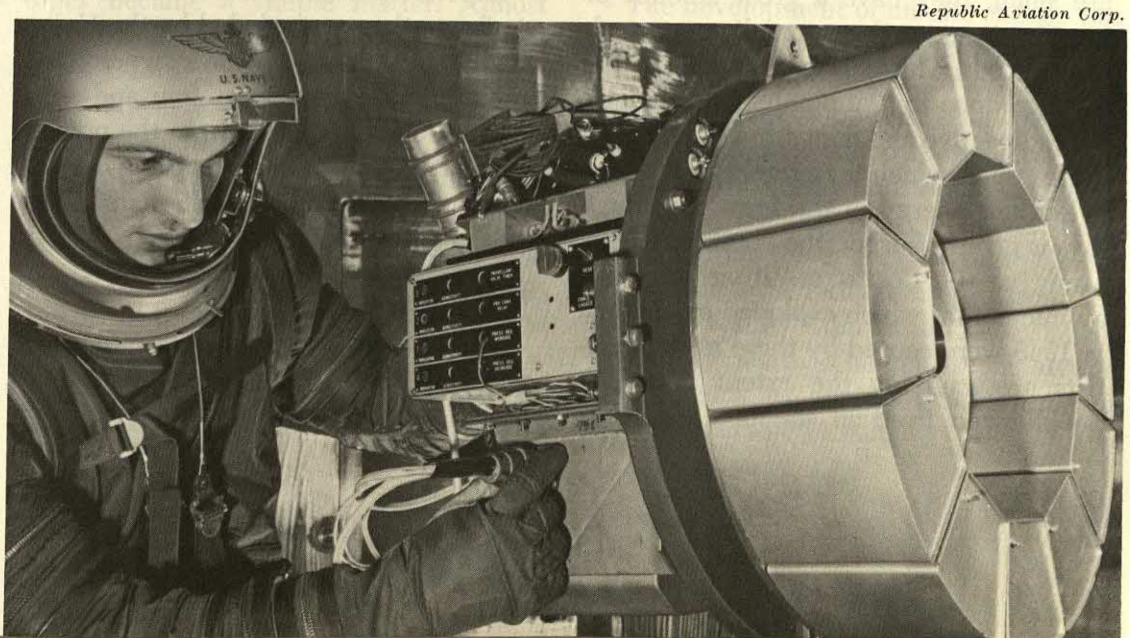
Controlled Fusion Reaction

Much research is being done in trying to attain a controlled fusion reaction. The most promising results seem to have been achieved with the ***pinched-plasma technique.*** Plasma is formed when hydrogen becomes an ionized gas. At that time, the deuterium atoms split into deuterons (${}_1\mathrm{H}^2$) and electrons at 100,000° C. The gas is held in a stream, or is pinched, by its own magnetic field, while the temperature is increased to the point necessary to start and sustain a fusion reaction.

One scientist estimates that if man can learn to use fusion for power, the hydro-

The pinched-plasma technique is being used in the space engine below. Fuel for the engine is a relatively inert gas, accelerated electromagnetically until it reaches a very high velocity. Gas directed from an exhaust nozzle provides thrust in direction opposite to the exhaust velocity.

Republic Aviation Corp.



gen in a pint of water will yield more energy than 1,000 tons of coal. There seems to be little doubt that for the first time in history man has available enough power either to destroy his civilization, or to raise the living standards of all people higher than he ever before dared hope.

USES OF ATOMIC ENERGY

The great power of atomic energy was first used for war. Highly destructive fission bombs were constructed in 1945. Since then, many peacetime uses for atomic energy have been developed.

Fission-Type Bomb (A-Bomb)

When a fission-type atomic bomb explodes, the heat near the center of the explosion approaches that of the sun. This heat is sufficient to turn steel into a vapor. This heat also makes the air expand rapidly. The rapid expansion causes a great deal of damage. Particles of the lighter elements produced when the atoms are split are hurled outward from the center of the blast at speeds almost equal to that of light. Even though the particles are small, they have a great amount of kinetic energy when traveling at such high speeds. This energy also adds to the damage done by the bomb. The particles are radioactive and dangerous to all living things upon which they settle.

Radiant energy in the form of gamma rays is given off when the bomb explodes. Many of the deaths resulting from the atomic bombs which exploded over Japan in 1945 were caused by these rays. Scientists are studying the extent to which people who lived in the bombed areas of Japan during World War II are still suffering from the effects of gamma rays.

Finally, the shower of neutrons which comes from an explosion of this type of bomb makes the area around the explosion radioactive. The radioactivity makes it dangerous for people to move into the bombed area until the radioactivity has had time to die away.

Fusion-Type Bomb (H-Bomb)

The fusion-type bomb is triggered by a fission bomb. Hence, the destructive effects just described are intensified by the additional energy released by the fusion action.

Why are H-bombs (hydrogen bombs) so powerful? First, fusion develops more energy per pound of material than fission does. Second, a fission bomb cannot contain more than a few pounds of uranium, or plutonium, or it will automatically explode itself. Thus its size is limited. But no matter how large a fusion bomb is made, it will not explode until its temperature is raised by the fission bomb which triggers it. There is, therefore, no natural limit to the size of the fusion bomb.

Experts estimate that a fusion bomb similar to the one exploded by the United States on March 1, 1954, would produce complete destruction four-and-a-half miles in every direction from the point at which it exploded, and moderate destruction from between four-and-a-half and ten miles in all directions.

Tracer Elements

Until 1934, the only known radioactive materials were those such as radium, which were found naturally in the earth.

In that year, the Curies' daughter, Irène, and her husband, Frédéric Joliot-(zhoh-lee-OH) Curie, announced that they had succeeded in producing radioactive elements in the laboratory. They had found that many of the lighter elements, such as aluminum, magnesium, and boron, when bombarbed with high-energy alpha particles, remained radioactive for varying amounts of time. Scientists recognized these radioactive elements as important aids to research and medicine. They were called ***tracer elements*** because they could be traced, with a Geiger counter, by their radiations, or by their effect on a photographic negative. They are actually artificial radioactive isotopes, or ***radioisotopes.*** They behave chemically like the stable element, but their radioactivity makes it possible for their presence to be detected very readily.

Although tracer elements were recognized to be of great importance, their use was limited by the fact that they were expensive to produce when they were made in a cyclotron.

With the successful development of the atomic pile, the production of radioisotopes became a simple matter. Almost any element becomes radioactive when left inside a nuclear reactor for a short time. Tracer elements are now prepared in large quantities.

Scientists are using tracer elements to discover how a number of biological processes, which are not yet completely understood, take place. For example, they do not yet understand exactly how photosynthesis is carried on by green plants.

Tracers of elements are being used to help solve the problem of photosynthesis. Carbon dioxide made with radioactive carbon is made available to the plant. It is hoped that, by following the tracer carbon dioxide in the green plant, its role in food manufacture can be learned.

If, and when, scientists understand the process of photosynthesis, they may be able to manufacture foods from carbon dioxide and water. Then man will no longer be dependent on green plants for his food supply.

Tracer elements are also being used to study ways in which different elements are used in the body. For example, it is important to know how sodium chloride is transported to, and used in, different parts of the body. When a patient is fed sodium chloride containing radioactive sodium, it is possible to trace its progress through the body.

Radioactive iodine is used in determining how well the thyroid gland is functioning. Radioisotopes are also used in the diagnosis of brain tumors and treatment of such diseases as cancer.

SUMMARY

The development of atomic energy was possible because of the discoveries made by scientists working in laboratories in many different countries. This development also demonstrated the effectiveness of the scientific method in solving many problems. Atomic energy differs from other sources of energy in that it does not originate in radiant energy from the sun, but results from fission or fusion of certain elements. The release of atomic energy adds to the potential source of energy available to man.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. The ray given off by radium that is similar to an x-ray is called (a) an alpha particle (b) a beta particle (c) a gamma ray (d) a neutron particle.

2. The atoms that were first split by man were atoms of (a) uranium (b) lithium (c) hydrogen (d) plutonium.

3. The splitting of an atomic nucleus into two parts is called (a) a chain reaction (b) radioactivity (c) fission (d) fusion.

4. Elements whose presence can be detected by their radioactivity are called (a) dangerous elements (b) chemically active elements (c) tracer elements (d) atomic elements.

5. Atomic energy has been made possible through the work of (a) American scientists only (b) scientists from many countries (c) English and Italian scientists only (d) English-speaking scientists only.

6. ${}_{1}H^{1}$ is the nuclear symbol for (a) an alpha particle (b) a proton (c) a helium nucleus (d) a hydrogen-3 nucleus.

7. ${}_{17}Cl^{35}$ is not (a) a chlorine nucleus (b) atomic number 17 (c) atomic mass 35 (d) neutron number 17.

8. The first of the modern atomic particle accelerators was the (a) Van de Graaff generator (b) cyclotron (c) synchrotron (d) bevatron.

9. Another name for a nuclear reactor is (a) cosmotron (b) atomic pile (c) accelerator (d) isotope.

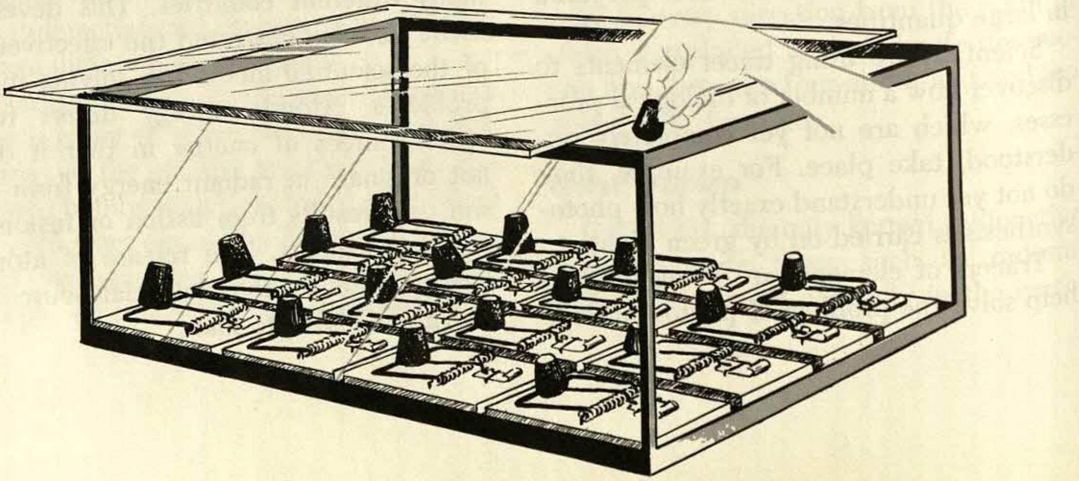
10. No track has ever been made in a Wilson cloud chamber for (a) an electron (b) a proton (c) an alpha particle (d) a neutron.

B. Making Observations

You can observe a simple type of chain reaction by preparing the setup below.

Obtain enough spring-type mousetraps to cover the bottom of an empty aquarium. Place the mousetraps in the aquarium and carefully set each one with a size 0 cork resting upon the tripper of each trap. After the traps are all set, drop a single cork on one of them. Observe the results. What do the mousetraps represent? What do the corks represent?

Write a single sentence stating how a chain reaction takes place.



Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the more important ideas in the unit.

1. How are natural materials from the earth used by man?
2. Why have synthetic materials been developed?
3. How might a scientist define matter?
4. What is meant by transformation of energy?
5. What is the relationship between weight and mass?
6. What is meant by weightlessness?
7. What would be the order, listed according to size, of the particles of matter from molecules to electrons?
8. What is believed to happen to the atoms in the formation of lithium fluoride (LiF) by electrovalent combination?
9. What is the purpose of building more powerful particle accelerators?

B. WORDS IN SCIENCE

List the numbers 1 through 16 on your answer sheet. Opposite each number write the letter of the item in the right-hand column which is most closely related to the numbered word.

1. alpha particle
2. atom
3. Einstein
4. gravity
5. isotopes
6. linear
7. mass
8. metal
9. molecule
10. non-metal
11. potential energy
12. proton
13. structural formula
14. valence
15. work
16. tracer element

a. formula
b. symbol
c. weight
d. inertia
e. $_2He^4$
f. combining characteristic
g. $_1H^1$
h. straight line
i. $E = mc^2$
j. zinc
k. force × distance
l. $_8O^{16}$, $_8O^{17}$
m. chlorine
n. stored
o. Geiger counter
p. H—O—H

You Can Go Further

A. BY DOING RESEARCH

1. The development of nuclear particle accelerators is full of interesting stories. Many magazines have carried these stories. They may be located through use of *The Readers Guide to Periodical Literature* in your library.

Individuals or committees from your class could each choose a different type of accelerator to look up and report on. Be sure the reports are given in the order of accelerator development so that you get the clearest picture. The *Scientific American* for March, 1958, might be a good place to start your research.

2. Make a list of all the instances in which you use energy obtained from chemical reactions.

B. BY PROBLEM SOLVING

1. Find the percentage composition of NaOH, of H_2SO_4, and of CaF_2.

2. How much work is done when you climb to the top of a 225-foot fire lookout tower?

C. BY READING

ASIMOV, ISAAC. *Realm of Measure*. Boston: Houghton Mifflin, 1960.
Ranges from the simplest measures of length to the highly complex ones used to measure the phenomena of force and energy.

FEIFER, NATHAN. *Let's Explore Chemistry*. New York: Sentinel Books, Inc., 1959.
Describes two hundred interesting, instructive, and safe experiments.

FERMI, LAURA. *The Story of Atomic Energy*. New York: Random House, 1961.
History of atomic research from Democritus up to, and including, the present-day developments.

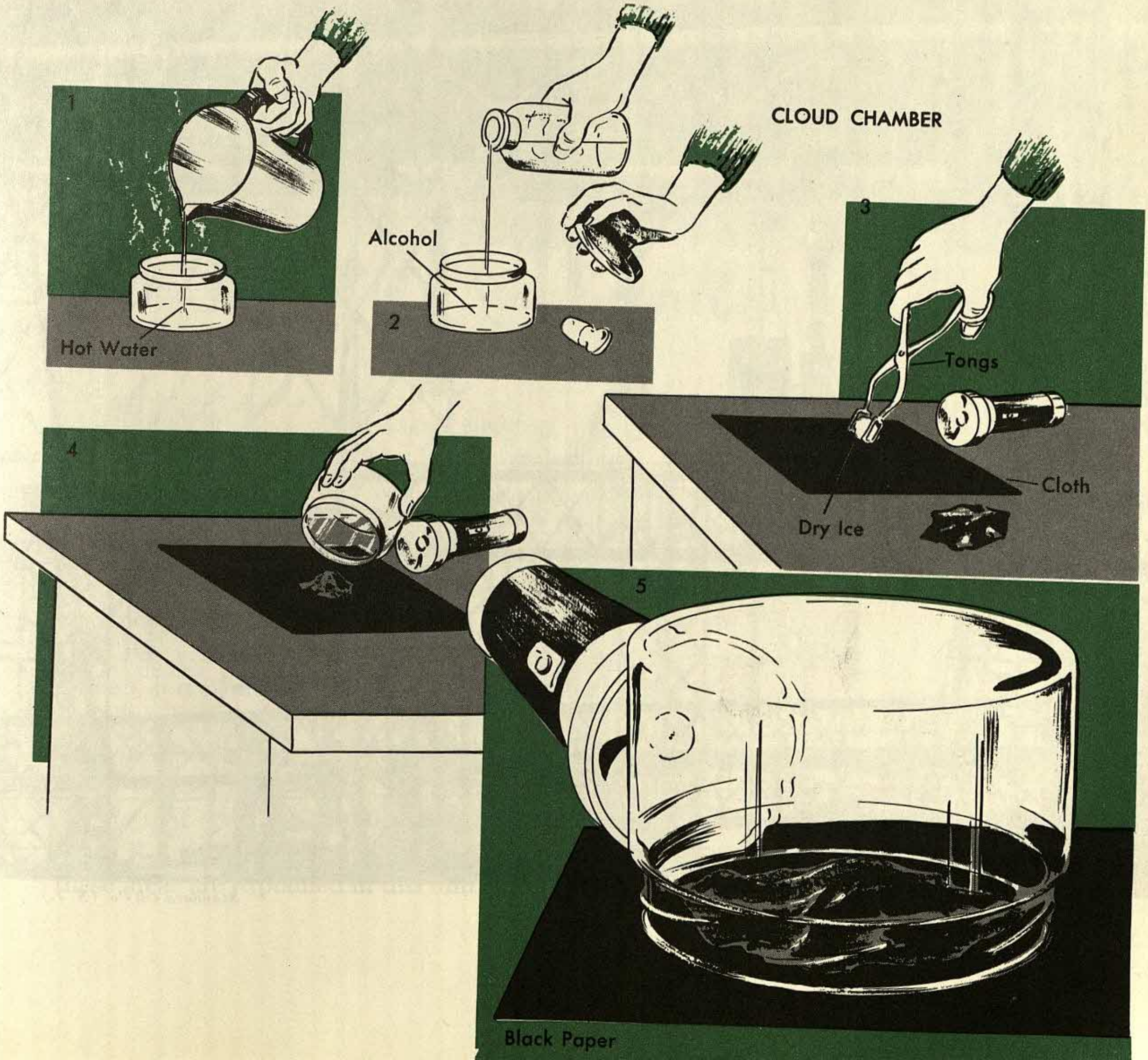
SEABORG, GLENN AND VALENS, E. G. *Elements of the Universe*. New York: E. P. Dutton and Company, Inc., 1958.
Describes discoveries of many of the heavier elements.

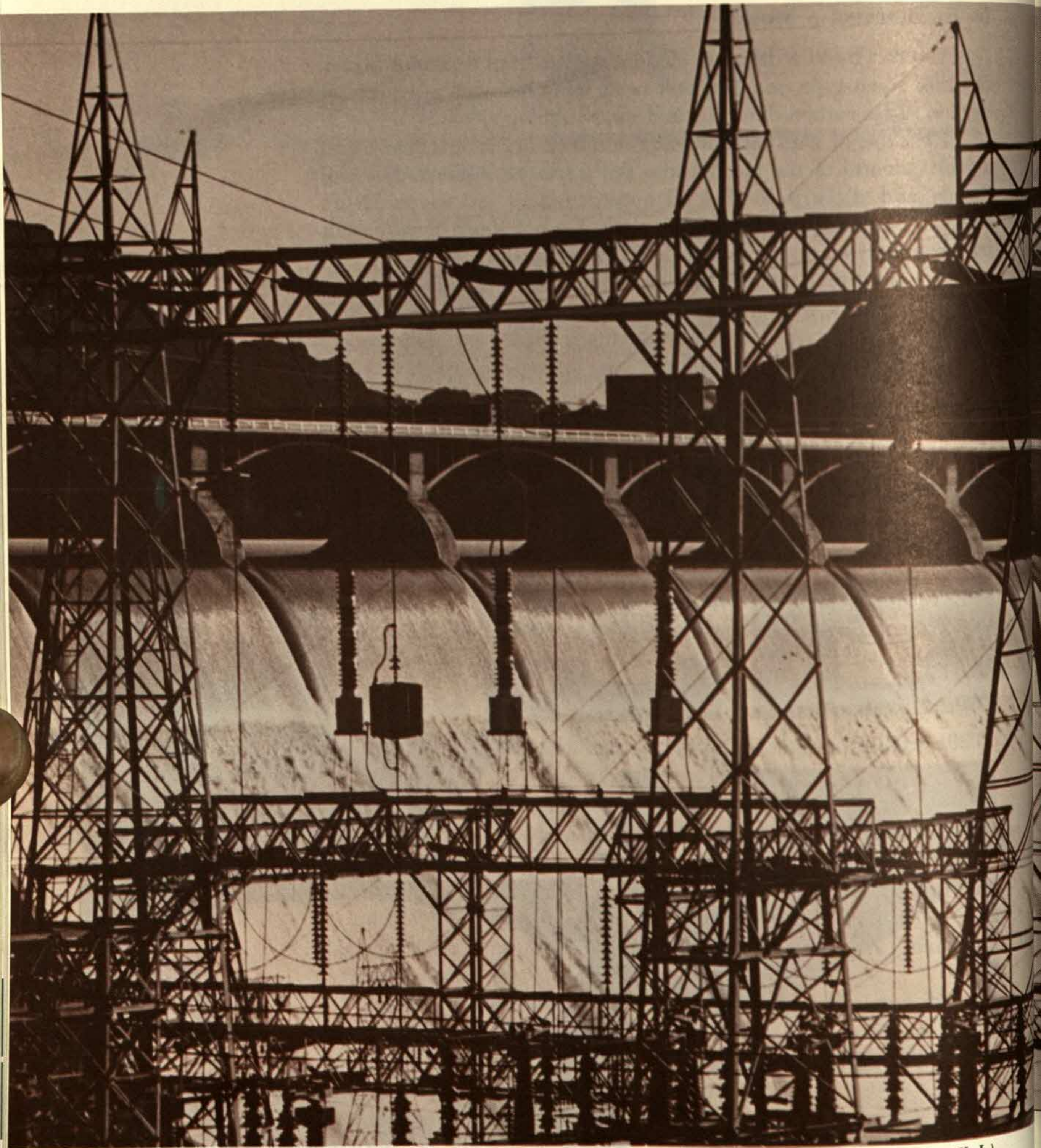
D. By Building a Model

You can build a diffusion cloud chamber from a peanut-butter, or other squat-type, jar. You will need some hot water, a piece of dry ice (solid carbon dioxide), and some rubbing alcohol.

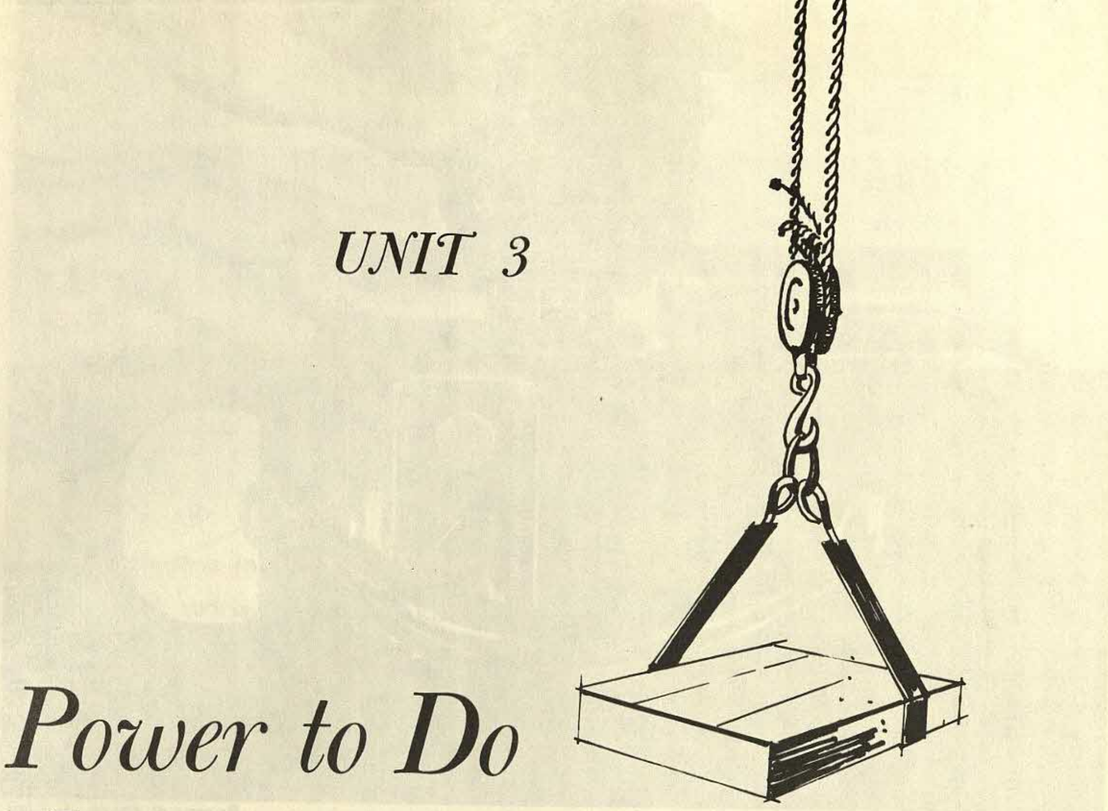
Heat the jar with the hot water and then dry it out. Pour about a tablespoonful of the alcohol into the warm jar. Immediately cap the jar and shake it so that all inside surfaces are covered with alcohol. Cover the dry ice with a cloth. Do not touch it with your bare hands. Then set the jar upside down on the dry ice.

In a short time a vapor trail should appear in the middle of the jar. Cosmic rays will produce about two tracks a minute. Better results can be obtained if the apparatus is placed on black paper, lighted from the side by a flashlight, and viewed in darkened room.





Standard Oil Co. (N. J.)



UNIT 3

Power to Do the World's Work

Since the days of Sir Isaac Newton, many scientists had believed that a space ship could be launched from earth some day. Before this could be done, however, a powerful engine had to be built. It had to be powerful enough to lift the space ship against the pull of the earth's gravity, and to continue to lift it beyond the earth's atmosphere. An interesting fact is that scientists knew exactly how powerful the new engine had to be. They knew this because, over the years, scientists had developed a system for measuring masses, forces, and distances. This system had made it possible for them to describe accurately how and why things move. With this knowledge, they were able to predict how much force it would take to lift a space ship beyond the earth. All that was needed was an engine that could do the job. Engineers finally built it. In order to build it, engineers had to use many scientific ideas. A number of these ideas are explained in this unit.

Bureau of Mines—U.S.D.I.

Scientist measures the intensity of a piece of radioactive material with a Geiger-type counter.

PROBLEM 1: HOW ARE WORK, ENERGY, AND POWER MEASURED?

Before anything can be measured, you must be sure to know what it is. In other words, you have to define it. Scientists have done this for everything they measure. In this problem, you will find a number of these definitions. Do not be frightened by them.

Power is defined as the rate of doing work. In Unit 2, you learned that work is measured by the product of a force and the distance through which the force acts. The formula for this is $w = f \times d$, where $w =$ work, $f =$ force, and $d =$ distance through which the force is applied. You will recall that work was measured in foot-pounds. It is well at this point for you to become familiar with computations of work and energy in systems of measurement other than the ones used everyday.

SYSTEMS OF MEASUREMENT

By definition, a force of about 980 dynes is needed to lift one gram of mass one centimeter. A dyne is a unit of force in the centimeter-gram-second CGS system of measuring. Other values are given in the table at the top of page 75.

Relationships Among Mass, Force, and Work

Mass	*Force*	*Distance*	*Work*
A mass of	requires a force of	to lift it against gravity. If lifted this distance,	the amount of work done is
1 slug	32 pounds	1 foot	32 foot-pounds
1 kilogram	9.8 newtons	1 meter	1 joule or 9.8 newton meters
1 gram	980 dynes	1 centimeter	980 ergs or 980 dyne centimeters

Work Calculations in the Metric System

How much work is done if a kilogram (1,000-gram) mass is lifted from the floor to a table 100 centimeters above the floor? If it takes 980 dynes to lift a gram mass a distance of one centimeter, it will take 1,000 times this, or 980,000 dynes to lift a kilogram (1,000 grams) of mass through the same distance. The work done in exerting this force through one meter (100 centimeters) equals 980,000 dynes times 100 centimeters.

A simple term, the erg, may be used in place of the awkward dyne-centimeters. You could say that 98,000,000 ergs of work were done. (One erg equals one dyne-centimeter.)

Although this is a long number, it represents such a small amount of work that a larger unit, the ***joule,*** has been put into use. One joule equals ten million ergs. You may now say that the work done is 9.8 joules. This figure was obtained by dividing 98,000,000 ergs by 10,000,000 ergs per joule.

Powers of Ten

In the metric system, prefixes may be added to names of basic units to indicate different quantities of each unit.

Both very large numbers (1 joule = 10,000,000 ergs) and very small numbers (1 microgram = .000000001 kilograms) are very common in science. To make

STATE INSTITUT
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UNIT	PREFIX	METRIC
1	none	gram
1/10	deci-	1 decigram = .1 gram
1/100	centi-	1 centigram = .01 gram
1/1000	milli-	1 milligram = .001 gram
$\frac{1}{1,000,000}$	micro-	1 microgram = .000001 gram
1,000 times	kilo-	1 kilogram = 1,000 grams

them easier to handle, a system has been devised based on the ***powers of ten.***

To understand the system, begin with numbers such as 10, 100, 1,000, 10,000, and 100,000. You know that 10 × 10 = 100. By the powers-of-ten system, you can write 100 as 10^2. This means 10 × 10 = 100. By this system, 1,000 can be noted as 10^3, which means 10 × 10 × 10. You can write 10,000 as 10^4, 100,000 as 10^5, and so on. You read 10^2 as ten to the second power, 10^3 as ten to the third, 10^4 to the fourth, and 10^5 to the fifth.

Summarized below is the powers-of-ten system for writing the following numbers.

$$\begin{array}{rr} 1 = 10^0 & 1{,}000 = 10^3 \\ 10 = 10^1 & 10{,}000 = 10^4 \\ 100 = 10^2 & 100{,}000 = 10^5 \end{array}$$

This is not only a convenient system for noting larger numbers, but also for multiplying, or dividing, such numbers. For example, if you multiply 100 × 100, you get 10,000. By this system, 100 is 10^2. To multiply $10^2 \times 10^2$, you merely add $2 + 2$ to get 10^4. As you will see above, 10^4 equals 10,000. If you divide 10,000 by 100, you get 100. By the powers-of-ten system, you subtract 2 from 4 to get 10^2.

To note a number such as 98,000,000 ergs by the powers-of-ten system would be much simpler than writing it out. First divide the number by ten by moving the decimal point one place to the left. If you divide by 10 again, you would move it one more place to the left. If you kept dividing by 10 until you reached the 9 in the large number, you would have divided by 10 seven times, and the decimal point would be between 9 and 8. You would have actually divided the large number by 10^7, or by 10,000,000 and would have come out with 9.8. By the powers-of-ten system, the large number would be written as 9.8×10^7 ergs. This is read as "nine point eight times ten to the seventh power ergs."

In all cases where large numbers are noted by the powers-of-ten system, the final number which is to be multiplied by 10 must be a number between 1 and 10. In noting 98,000,000 ergs, that number is 9.8.

The powers-of-ten system is also used to write very small numbers. For example, the mass of a hydrogen atom is 0.0000000000000000000000017 gram. To write this number in the powers-of-ten system, you would move the decimal point to the right twenty-four places. It would then be placed between 1 and 7 and written 1.7. The number to indicate the power-of-ten would be written −24. The minus sign shows that the decimal point has been moved to the right. The mass of a hydrogen atom would be written 1.7×10^{-24}. This is read, "one point seven times ten to the minus twenty-fourth power." The powers-of-ten system for writing small numbers is as follows:

$$\begin{array}{r} 1 = 10^0 \\ 0.1 = 10^{-1} \\ 0.01 = 10^{-2} \\ 0.001 = 10^{-3} \\ 0.0001 = 10^{-4} \\ 0.00001 = 10^{-5} \end{array}$$

Energy Calculations

The 1,000-gram mass resting on a table, referred to on page 75, is said to have energy because of the work it could do in falling to the floor. As you learned in Unit 2, this stored energy is called potential energy. The work it could do is equal to the work done on the mass in raising it to the table—9.8 joules. Therefore, its energy, or ability to do work, is 9.8 joules. In lifting a can of fruit weighing one pound through one foot, one foot-pound of energy is added to it. Can you show that this would equal about 1.356 joules?

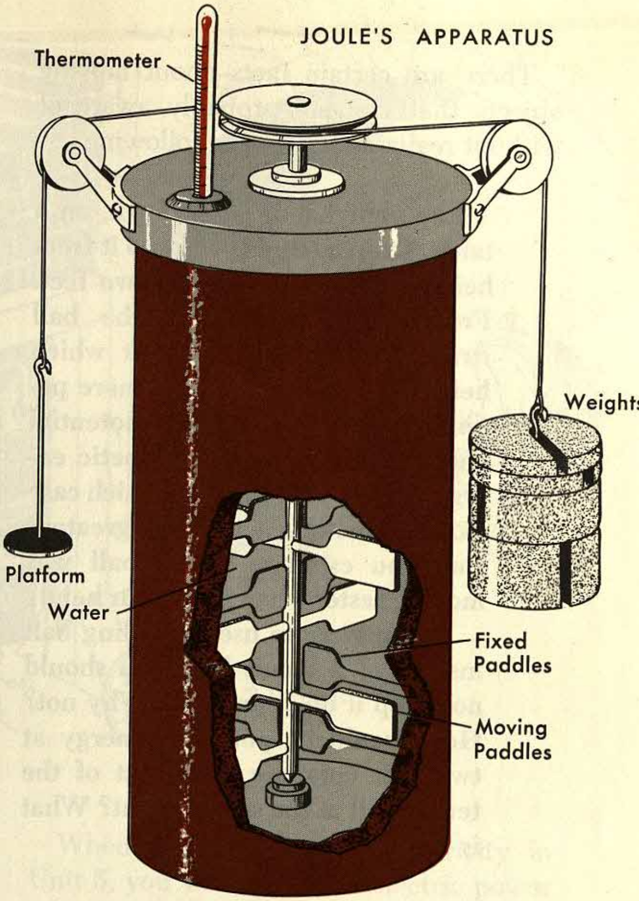
Energy in Heat Units

In chemical and nuclear equations, the energy involved is frequently in terms of heat energy. When using a saw, or even in rubbing your hands together, heat results from the work done.

Heat energy can be measured in ***calories***, or in ***British thermal units*** (***Btu***). A Btu is the amount of heat energy necessary to raise the temperature of one pound of water 1° F. A ***calorie*** is the amount of heat energy required to raise the temperature of one gram of water 1° C.

About 100 years ago, James Prescott Joule completed fifteen years of experimentation in which he did measurable amounts of work in measured quantities of water. He noted the temperature rise in each case. The results of his experiments, and of many others like them, indicate that it takes 4.186 joules of work to produce one calorie of heat. His name was chosen for this unit to recall his contribution to knowledge in this field.

From Joule's work the conclusion follows that anything which can raise the temperature of water has the ability to do work. When sunshine heats water, it does work on the molecules of water. Hence, sunshine has energy. In fact, at noon of a sunny day, solar energy may fall on a square mile of the earth's surface at a rate as high as two-and-a-quarter trillion (2.25×10^{12}) joules per second. At the present time, most of this great supply of solar energy is not used by man. But more and more attention is being given to developing methods of using it.


JOULE'S APPARATUS

Kinetic Energy Calculations

Kinetic energy is the energy of motion. The motion of molecules of matter gives rise to kinetic energy as heat. A moving automobile develops kinetic energy because of its motion.

There are certain facts about moving objects that you are probably aware of without realizing it. Try the following:

> **Lay your hand, palm down, on a table. Drop a tennis ball onto it from heights of two inches and two feet. From which height did the ball strike the sharper blow? At which height did the ball possess more potential energy? If all this potential energy were released as kinetic energy against your hand, in which case would kinetic energy be greater? Can you estimate which ball was moving faster when it hit your hand?**
>
> **If you were to use a bowling ball instead of a tennis ball, you should not drop it on your hand. Why not? How would its potential energy at two feet compare with that of the tennis ball at the same height? What is the obvious difference?**

It has been found that the kinetic energy of a moving object can be calculated if you know its mass and its ***velocity.*** Velocity tells not only the speed of a motion, but its direction as well. The mathematical relationship is expressed as $KE = \frac{1}{2} mv^2$. This means that the kinetic energy of a moving object equals one half the product of the mass of the moving object and the square of its velocity.

If a mass of 200 grams is moving at 5 cm/second, the kinetic energy is 2,500 ergs ($\frac{1}{2} \times 200 \times 5 \times 5$). If a mass of 400 grams is substituted, the kinetic energy becomes 5,000 ergs ($\frac{1}{2} \times 400 \times 5 \times 5$). With a mass of 400 grams and a speed of 10 cm/second, the kinetic energy is now found to be 20,000 ergs ($\frac{1}{2} \times 400 \times 10 \times 10$).

From the above examples it can be seen that if the mass is doubled, the kinetic energy is doubled. If the speed is doubled, the kinetic energy becomes four times as great. Or, to put it another way, an automobile traveling at 60 miles per hour has four times the destructive ability that it has when it is traveling 30 miles an hour, not just twice as much.

How many ergs of kinetic energy does each of the following have?

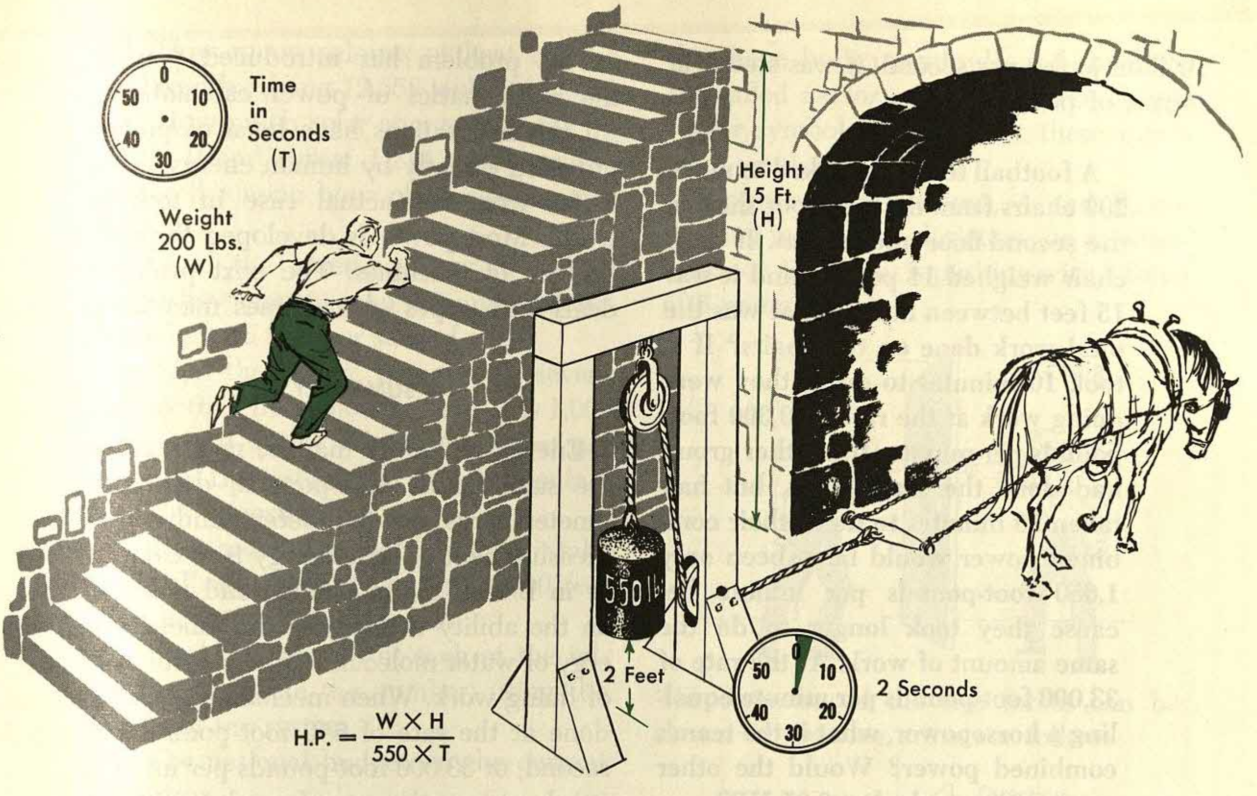
	Mass In Grams	**Velocity In Cm/sec.**
1.	**50**	**70**
2.	**162**	**100**
3.	**2,000**	**55**
4.	**5**	**25**

POWER

Scientists use the word power to describe the rate at which work is done.

You know that it is more difficult to run up stairs than to climb them slowly. And yet the amount of work done in each case is exactly the same.

Suppose, for example, a man weighing 200 pounds walked up a 15-foot stairway. He would have done 3,000 (200 pounds × 15 feet) foot-pounds of work. Now suppose this man should run up the same stairs in one half the time it took him to walk up them. He would still be doing only 3,000 foot-pounds of work, but he would be doing them in one half the time. The difference between walking and running up the stairs is in time, not in work.



The 200-pound man had to produce twice as much power to run up the stairs as to walk up them. It is the extra power required that makes it more difficult to work rapidly.

Meaning of Horsepower

A Scottish scientist, James Watt, is credited with establishing one of the basic units of measuring power. Seeing a need for some unit with which to measure power, he is said to have carried on experiments to determine how much work a good horse could do. Estimating that the best horses could do 33,000 foot-pounds of work per minute, he established 33,000 foot-pounds per minute as one ***horsepower.*** The value has never been changed.

When you study about electricity in Unit 5, you will learn that electric power is measured in watts rather than in horsepower. However, watts can be converted easily into horsepower. Experiments have shown that 746 watts are equal to one horsepower. An electric motor using 1,492 watts of electricity is a two-horsepower motor.

Power Calculations

It is possible to calculate power by finding the work done in a unit of time because Power $= \frac{\text{Work}}{\text{Time}}$. When it was stated earlier that solar energy falls on the earth's surface at a rate of two-and-a-quarter trillion joules per second, it was stated in terms of power.

A football team was asked to move 200 chairs from the first-floor shop to the second-floor auditorium. If each chair weighed 11 pounds and it was 15 feet between floors, what was the total work done on the chairs? If it took 10 minutes to do it, they were doing work at the rate of 3,300 foot-pounds per minute. If another group had done the same work, but had taken 20 minutes to do it, their combined power would have been only 1,650 foot-pounds per minute because they took longer to do the same amount of work. At the rate of 33,000 foot-pounds per minute equalling a horsepower, what is the team's combined power? Would the other group have worked at 0.05 HP?

This problem has introduced you to the mathematics of power calculations. All the illustrations have been of power provided directly by human energy. This is far from the actual case in today's world. Most power is developed through the use of machines. The next problem deals with types of machines man uses.

SUMMARY

Energy and work may be measured in the same units: foot-pounds, dyne-centimeters, ergs, newton-meters, and joules. Measurement of heat energy is in calories or in British thermal units, and is based on the ability to increase the kinetic energy of water molecules. Power is the rate of doing work. When mechanical work is done at the rate of 550 foot-pounds per second, or 33,000 foot-pounds per minute, it is known as the rate of one horsepower.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. The factor which is used in measuring power, but which is not used in measuring work is (a) push or pull (b) distance (c) force (d) time.

2. A dyne is a unit of (a) force (b) mass (c) work (d) power.

3. Three million may be represented by (a) 3 mills (b) 3,000,000,000 (c) 3×10^6 (d) 300×10^5.

4. One horsepower is equal to work done at the rate of (a) 550 ft. lb./min. (b) 550 ft. lb./sec. (c) 33,000 ft. lb./sec. (d) 33,000 ft. lb./hour.

5. Heat energy can be measured in (a) degrees C (b) degrees F (c) dynes (d) British thermal units.

B. Solving Mathematical Problems

1. Find the kinetic energy of a mass weighing 0.5 gram and moving at 300,000 cm./sec.

2. Change 350,000,000 ergs to joules.

3. How many calories of heat can be produced by doing 12,558 joules of work?

4. How much solar energy may fall on Rhode Island (area: 1,214 square miles) during the noon hour of a midsummer's day?

5. Find the kinetic energy of a 100-pound boy (mass) who is running down the hall at 15 feet per second.

6. Find the kinetic energy of a seven-man football line whose total mass is 1,000 pounds and whose velocity is 10 feet per second at the instant that it makes contact with the opposing line.

7. How many horsepower would it take to lift all members of your class 100 feet in an elevator in 10 seconds?

8. Find the amount of each of the following and write the number, using the powers-of-ten system.

a. The national budget for the current fiscal year

b. Population of the United States

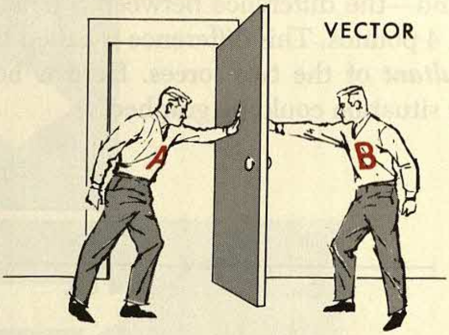
c. Mean distance from earth to sun

d. A light year in miles

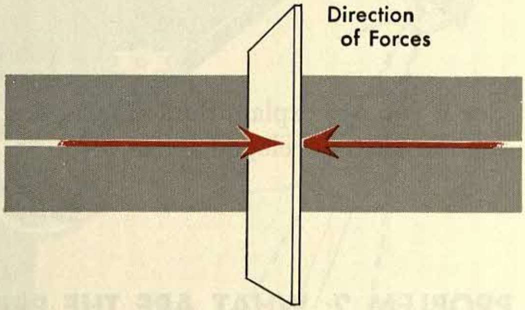
C. *Graphing Forces*

All forces such as those referred to in the table on page 75 have two characteristics. The characteristic shown in the table is size, or magnitude. As you can see in the table, the magnitude of a force is expressed in such units as pounds, newtons, or dynes, depending on which system of measurement you are using. The other characteristic of a force is its direction. The diagrams on page 21 in Unit 2 show how direction of the force of gravity can be indicated by using the arrowhead. The length of arrow can also be used to show the magnitude of the force. Quantities that have both magnitude and direction are called ***vector*** quantities. Here is how vector symbols to represent these quantities are drawn.

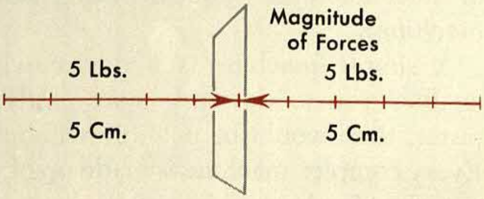
Suppose that two boys, A and B, are pushing in opposite directions on a swinging door. Each boy is pushing with a force of 5 pounds.



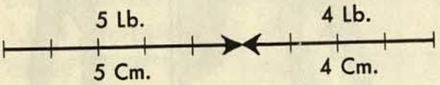
The direction of the two forces can be shown by drawing arrows as follows:

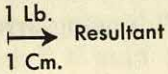


The magnitude of the forces can be shown by representing one pound of force by one centimeter and by drawing each arrow five centimeters long, as follows:

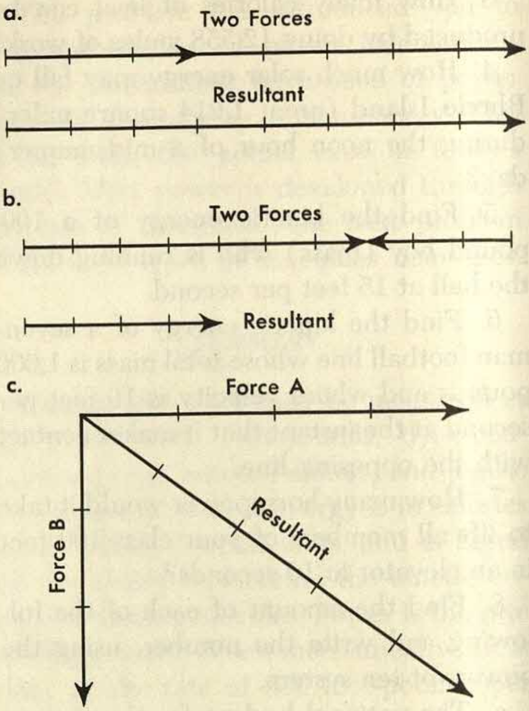


Under these conditions, the door would not move in either direction. However, if A were pushing with a force of 5 pounds, and B were pushing with a force of 4 pounds, what would happen? You can see that the door would open slowly in the direction that A was pushing. It would move in that direction with a force of 1 pound—the difference between 5 pounds and 4 pounds. This difference is called the ***resultant*** of the two forces. Here is how this situation could be graphed:





See if you can explain the following by using the ideas developed above.



Now make up some situations such as the above and see if your classmates can show what will happen by drawing graphs.

PROBLEM 2: WHAT ARE THE PRINCIPLES OF THE SIMPLE MACHINE?

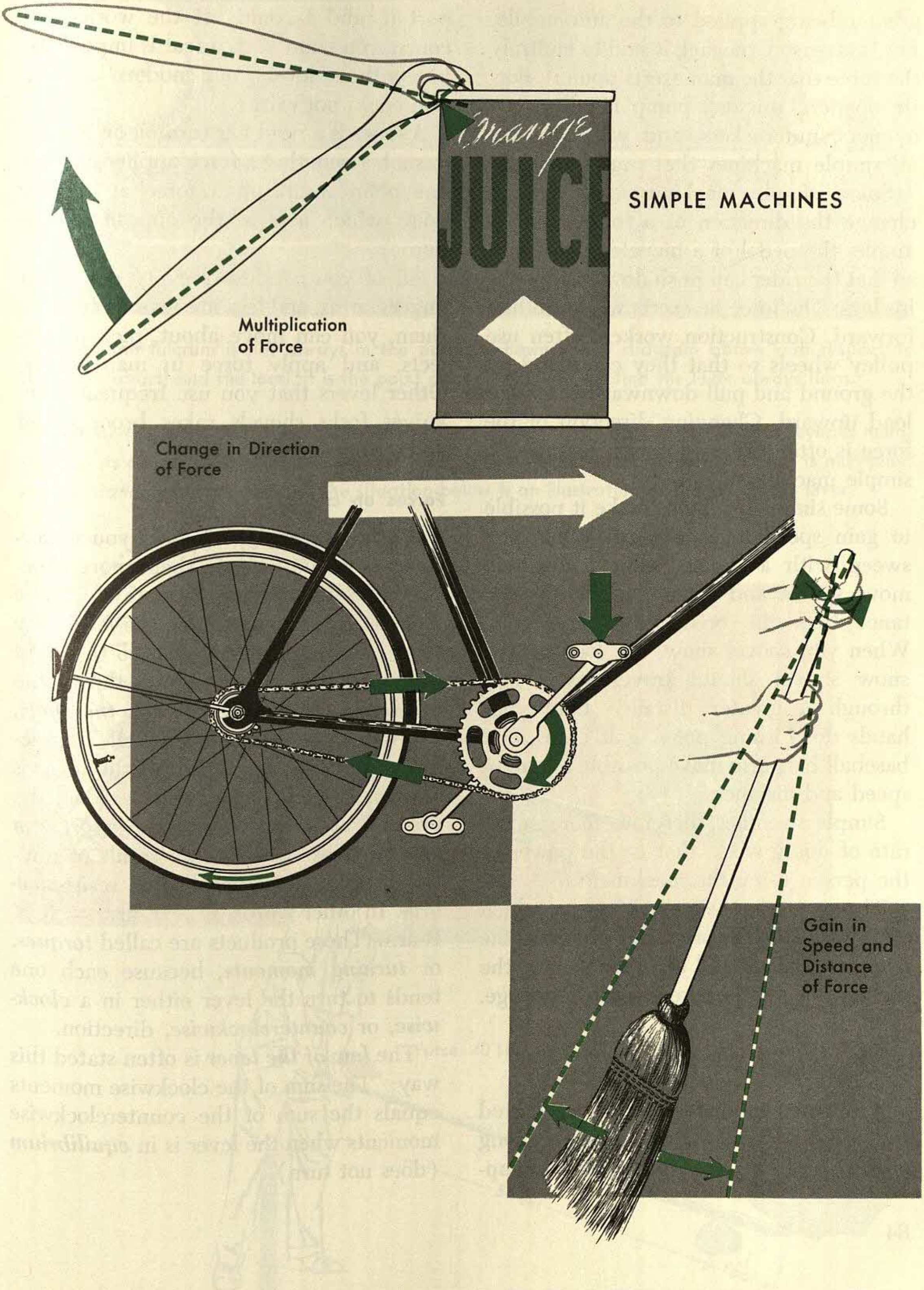
Every time you use a knife or fork, sweep a floor with a broom, twist a screwdriver, climb a stairway, turn a door knob, or steer a bicycle, you are using ***simple machines.***

A simple machine is a device which enables you to do work more easily, or faster, than would be possible without it. Every complex machine is made up of two or more simple machines.

TYPES AND PURPOSES

Some simple machines make it possible to multiply force. Suppose it were necessary to change a flat tire on an automobile. A man cannot exert enough force to lift the automobile so that the tire can be changed. But, with an automobile jack, the force which he exerts on the handle of the jack results in a force many times

SIMPLE MACHINES


Orange
JUICE
Multiplication of Force
Change in Direction of Force
Gain in Speed and Distance of Force

greater being applied to the automobile. For this reason, the jack is said to multiply the force that the man exerts upon it. Bottle openers, scissors, pump handles, can openers, nutcrackers, and wrenches are all simple machines that multiply force.

Some simple machines are used to change the direction of a force. For example, the pedal of a bicycle is arranged so that the rider can push downward with his legs. The force he exerts will push him forward. Construction workers often use pulley wheels so that they can stand on the ground and pull downward to raise a load upward. Changing direction of the force is often the only reason for using a simple machine.

Some simple machines make it possible to gain speed and distance. When you sweep with a broom, your hands will move slower and through a shorter distance than the bristles of the broom. When you shovel snow, the load on the snow shovel should travel faster and through a greater distance than your hands do. Fishing poles, golf clubs, and baseball bats also make possible a gain of speed and distance.

Simple machines, therefore, increase the rate of doing work, that is, the power of the person using the machine.

There are six basic machines on which all other machines are built. They are the lever, the wheel and axle, the pulley, the inclined plane, the screw, and the wedge.

THE LEVER

A scientist in ancient times is reported to have once said, "Give me a lever long enough, and a place upon which to support it, and I could lift the world." Of course you know such a feat is impossible, but without levers, our modern civilization could not exist.

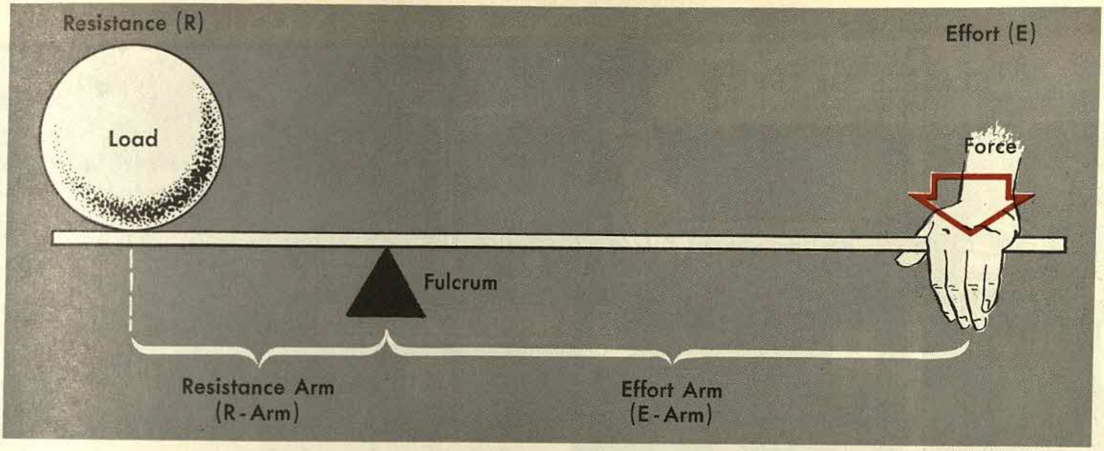
A ***lever*** is a rigid bar turning on a point in such a way that a force applied on it at one point results in a force at another point which acts in the opposite direction.

All of you use levers every day. Your fingers, arms, and legs are levers. By using them, you can move about, pick up objects, and apply force in many ways. Other levers that you use frequently are knives, forks, shovels, rakes, brooms, golf clubs, and scissors.

Forces on a Lever

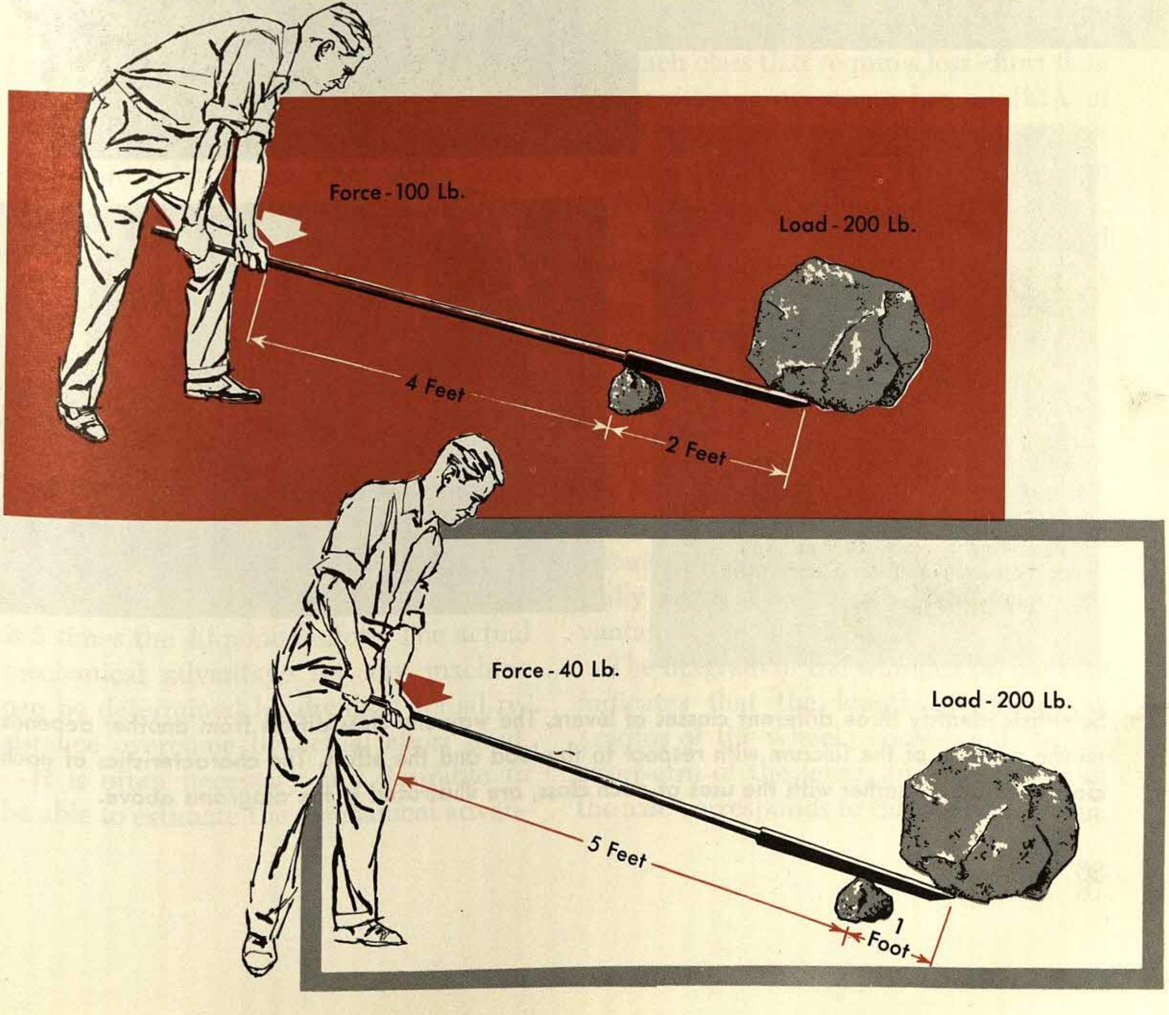
A study of levers will help you understand how you can use them more effectively. In the diagram on page 85, notice that the point about which the lever may turn, called the ***fulcrum,*** is also the point supporting the weight of everything—the ***resistance*** (load), the ***force*** or ***the effort,*** and the weight of the lever itself. In practical problems, the weight of the lever is often neglected. When this is done, the product of the ***effort*** and the ***effort arm*** are taken as equal to the result of multiplying the resistance by the ***resistance-arm.*** In other words, E × E-arm = R × R-arm. These products are called ***torques,*** or ***turning moments,*** because each one tends to turn the lever either in a ***clockwise,*** or ***counterclockwise,*** direction.

The ***law of the lever*** is often stated this way: "The sum of the clockwise moments equals the sum of the counterclockwise moments when the lever is in ***equilibrium*** (does not turn).

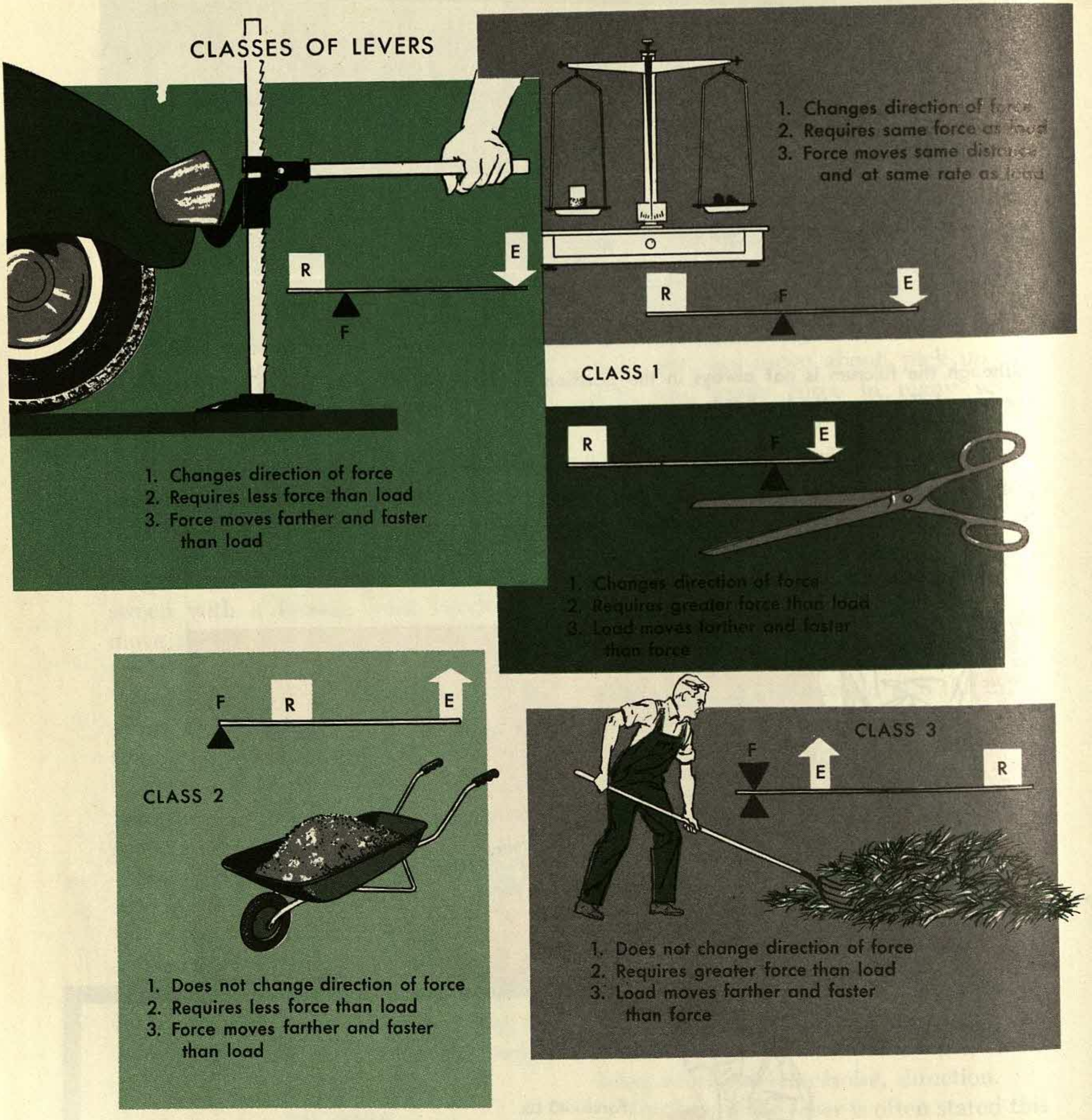


Although the fulcrum is not always in the position shown in the diagram above with respect to the force (effort) and the load, it is the point about which you will find the lever always turns.

The law of the lever, illustrated below, states that whenever the force applied to a lever is multiplied by its distance from the fulcrum, the result is always the same as when the load is multiplied by its distance from the fulcrum. The situation below is an illustration of the law of the lever.


Force - 100 Lb.
Load - 200 Lb.
4 Feet
2 Feet
Force - 40 Lb.
Load - 200 Lb.
5 Feet
1 Foot

CLASSES OF LEVERS



1. Changes direction of force
2. Requires less force than load
3. Force moves farther and faster than load

1. Changes direction of force
2. Requires same force as load
3. Force moves same distance and at same rate as load

CLASS 1

1. Changes direction of force
2. Requires greater force than load
3. Load moves farther and faster than force

CLASS 2

1. Does not change direction of force
2. Requires less force than load
3. Force moves farther and faster than load

CLASS 3

1. Does not change direction of force
2. Requires greater force than load
3. Load moves farther and faster than force

Scientists identify three different classes of levers. The way one class differs from another depends on the position of the fulcrum with respect to the load and the effort. The characteristics of each class of levers, together with the uses of each class, are illustrated in the diagrams above.

Effect of Forces

Applications of the law of the lever are illustrated on page 86.

Study the diagram at the bottom of page 85. If the stone used as a fulcrum had been placed three feet from the 200-pound load, how much effort would have to be applied? Draw your own diagram and use the law of the lever to help you find the answer. It can easily be seen that the position of the fulcrum determines the length of the two arms and the relation of the resistance to the effort. These ratios can be written as follows:

$$\frac{\text{E-arm}}{\text{R-arm}} = \frac{\text{Resistance}}{\text{Effort}}$$

Such a relationship is called an ***inverse proportion.*** The *longer* the effort-arm is as compared to the resistance arm, the *less* the effort needs to be for the same resistance. Check this in each diagram. The relative position of the effort, resistance, and fulcrum can change the characteristics of a lever's action greatly. See the explanation of classes of levers on page 86.

Mechanical Advantages

When a 100-pound effort can balance a 200-pound load, the resistance is twice as great as the force applied to the machine. In such a case, it is said that there is an ***actual mechanical advantage*** (***AMA***) of 2. In the bottom diagram on page 85, the AMA would be 5, as the 200-pound load is 5 times the 40-pound effort. The actual mechanical advantage for any machine can be determined by dividing actual resistance overcome by actual effort used.

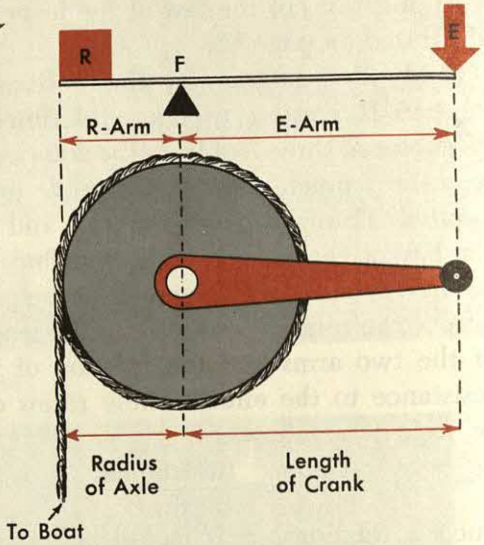
It is often necessary and desirable to be able to estimate the mechanical advantage of a machine before it is built. Because of the friction and weight of the lever, which you have been disregarding, the AMA will never equal the estimated, or ***ideal mechanical advantage*** (***IMA***). The ideal mechanical advantage of a lever can be found by dividing the E-arm by the R-arm. In the second diagram on page 85, 4 feet divided by 2 feet equals an IMA of 2. This IMA must be equal to the AMA in this illustration because you ignored those things which cause them to differ. When the fulcrum is in the middle of the lever, the IMA is equal to 1 and all the machine does is change the direction of the action of the forces—that is, you push down and the load moves up. The effort equals the resistance.

In the diagrams of lever classes on page 86, each class that requires less effort than the resistance overcome has an IMA of more than 1. Those needing more effort than resistance have an IMA of less than 1. Note that when the IMA is less than 1, the resistance always moves farther and faster than the effort. The condition is often spoken of as a ***speed advantage.***

THE WHEEL AND THE AXLE

Although levers can be made to multiply the effort applied ten, or even twenty, times, the distance through which the resistance moves is relatively small, especially for levers of high mechanical advantages.

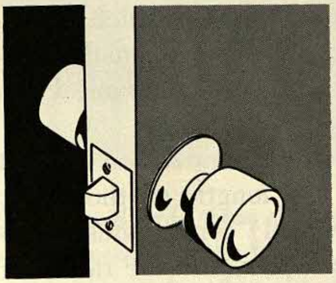
The diagram of the windlass on page 88 indicates that the length of the crank (radius of the wheel) corresponds to the effort-arm of the lever, and the radius of the axle corresponds to the resistance-arm.

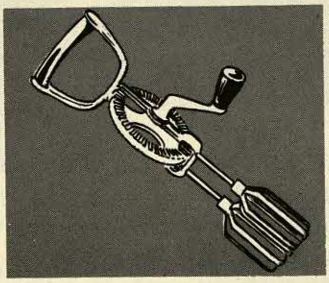


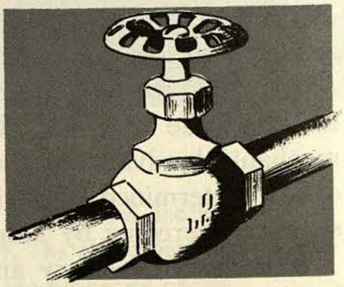
Thus, the wheel and the axle can be considered a rotary lever with the axle as the fulcrum. There is almost no limit to the length of the rope which can be used. The length of the rope alone determines the distance that the resistance can be moved. The AMA is still found by taking the ratio of R to E and the IMA by taking the ratio of the E-arm to the R-arm. In this case, however, the E-arm is seen to be the radius of the wheel (length of the handle), and the R-arm, the radius of the axle. When using the wheel and axle, the formula for finding the IMA is:

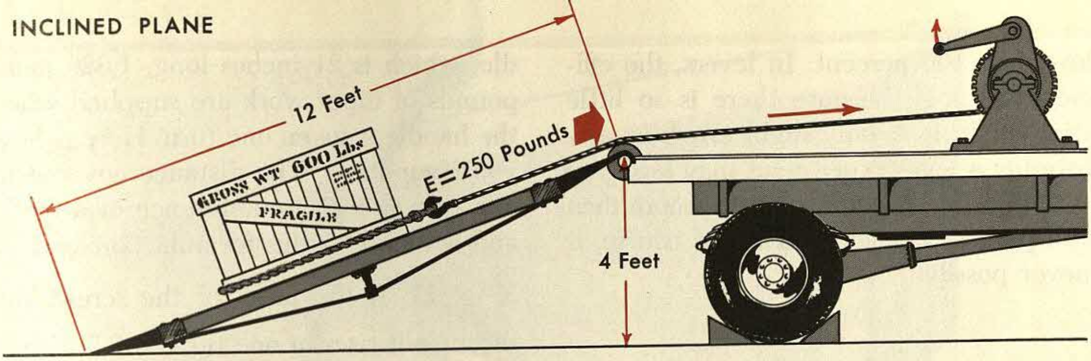
$$\text{IMA} = \frac{\text{Radius of wheel}}{\text{Radius of axle}}.$$

The steering wheel of an automobile is also an example of this simple machine. The effort is applied to the rim of the wheel, while the load is the resistance to be overcome in turning the front wheels. The axle connected to the steering wheel moves the load and turns the front wheels. Other examples are given below.









THE INCLINED PLANE

When men load and unload heavy objects from a truck, they often use another simple machine, the inclined plane. This is merely a long plank, or platform, extending from the ground to the truck, up or down which the load is moved. This one, like other simple machines, can be used to multiply force. The IMA and the AMA are never equal in this machine because of the energy wasted in overcoming the friction of the object sliding, or rolling, on the plane. The ideal is always larger than the actual.

On this page is a diagram which shows a 600-pound crate being moved by a 250-pound pull along a 12-foot plank into a truck 4 feet above the ground. Therefore, the AMA is 2.4 $\left(\text{from } \frac{600}{250}\right)$. The 250-pound force being exerted parallel to the 12-foot plank is lifting the crate 4 feet straight up against the 600-pound pull of gravity. Calculate the work done by the effort of 250 pounds. This force is moving the crate along the 12-foot length of plank so that work done is 3,000 foot-pounds. Because this energy is put into the machine to do the 3,000 foot-pounds of work, it is called the ***work input,*** or just ***input.***

Now how much work do you get out of this machine? The work done on the resistance is called the ***work output,*** or ***output.*** Since the 600-pound crate has been lifted 4 feet, the output is equal to 2,400 foot-pounds. Notice that there is less work output than there is input. If there had been more friction, the difference would have been even greater. You might have lowered the friction loss by greasing the plank and thus reducing the wasted energy. The ratio of output to input is called ***efficiency,*** and it is usually expressed as a percent. This machine is only 80 percent efficient. This means that only .80 of the work done by the effort was useful in producing work on the resistance, that is, (2,400 ft. lbs. ÷ 3,000 ft. lbs. = .80).

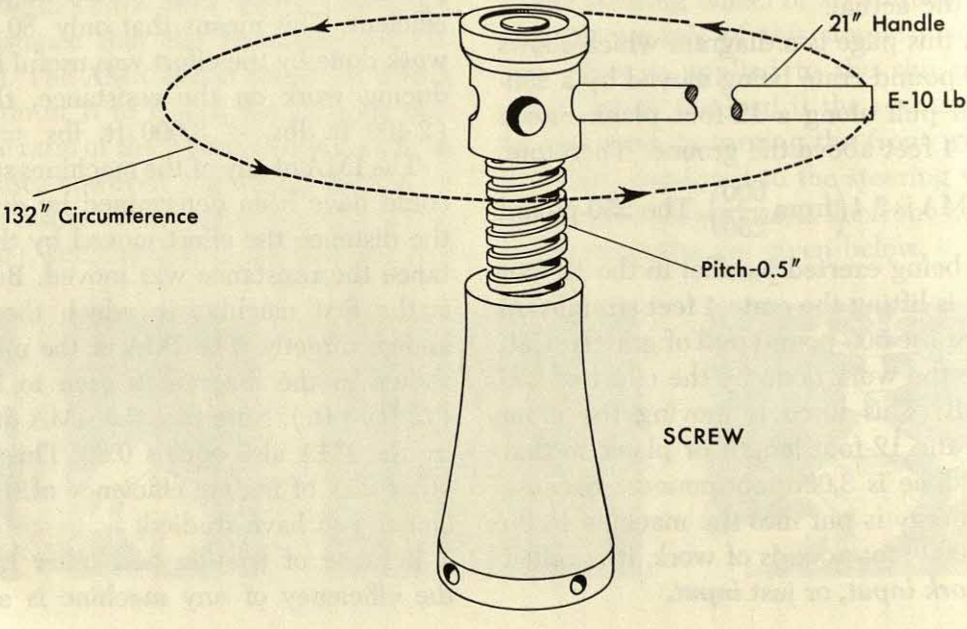
The IMA of any of the machines studied could have been determined by dividing the distance the effort moved by the distance the resistance was moved. But this is the first machine in which these are known directly. The IMA of the machine shown in the diagram is seen to be 3.0 (12 ft./4 ft.). Note that the AMA divided by the IMA also equals 0.80. This is another way of finding efficiency of the machines you have studied.

Because of friction and other factors, the efficiency of any machine is always less than 100 percent. In levers, the efficiency is high because there is so little friction. In fact, only slight errors in performing a lever experiment may lead you to think you have a machine of more than 100 percent efficiency! This, of course, is never possible.

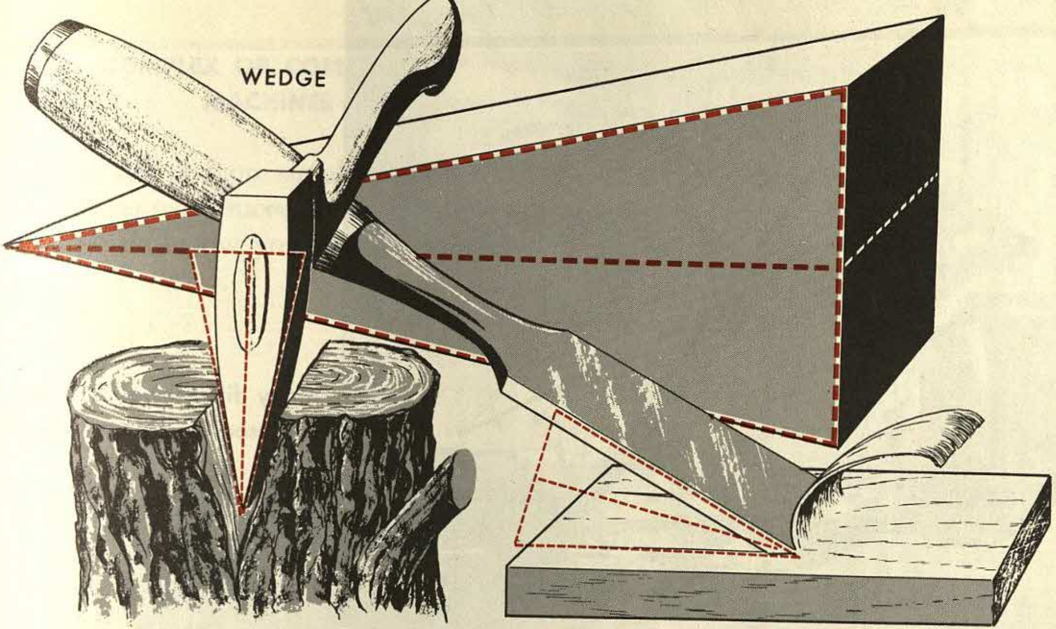
THE SCREW

A common wood screw is an example of one of the most widely used simple machines. The threads are arranged as an inclined plane which winds around the screw. Propellers on airplanes and ships are built so that when they turn, they act as screws.

A jack screw has the highest IMA and the lowest efficiency of any of the simple machines. When an effort of 10 pounds is applied to the end of the jack screw handle, which is 21 inches long, 1,320 inch-pounds of input work are supplied when the handle is given one turn. Here is how you compute it. The distance covered in one turn is the circumference of a circle and is found by this formula: $2\pi r$ or $2 \times \frac{22}{7} \times 21$. If the *pitch* of the screw, the distance it rises in one turn, is 0.5 inches, the IMA is found to be 264. Remember, IMA is found by dividing the distance the effort arm moved (132″) by the distance the resistance was moved (0.5″). Assume that the load which it can lift is 1,056 pounds. In one turn, it lifts this ½″. It, therefore, does 528 inch-pounds of work. The efficiency is only 40 percent. Can you check these figures? But notice that the machine lifts more than half a ton with only a 10-pound effort. That is why jack screws are used to raise small buildings short distances.



SCREW



THE WEDGE

The blade of an axe or hatchet is constructed so that both sides slope away from the cutting edge and thus form a V. A line from the point through the middle of the V shows that the axe is really two inclined planes.

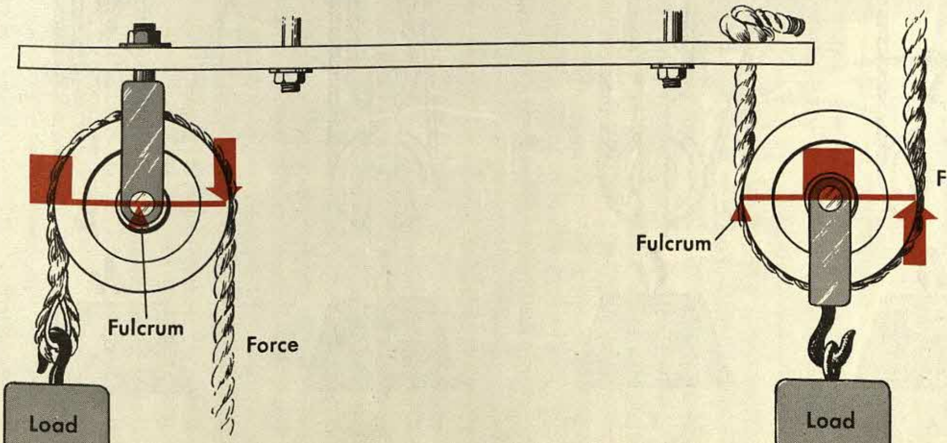
The wedge is a useful device but a very difficult one about which to make calculations. Its IMA is usually figured by dividing its length by its greatest thickness. Some applications of the wedge in use are shown above.

PULLEYS

There are two types of pulleys, the ***fixed*** and the ***movable.*** The movable pulley is always attached to the load to be moved. The diagram below compares each type to a different class of lever.

Pulleys are commonly used in combinations known as ***pulley systems,*** or the ***block and tackle.*** The IMA of these combinations is found by counting the number of strands of rope supporting the movable section to which the load is attached.

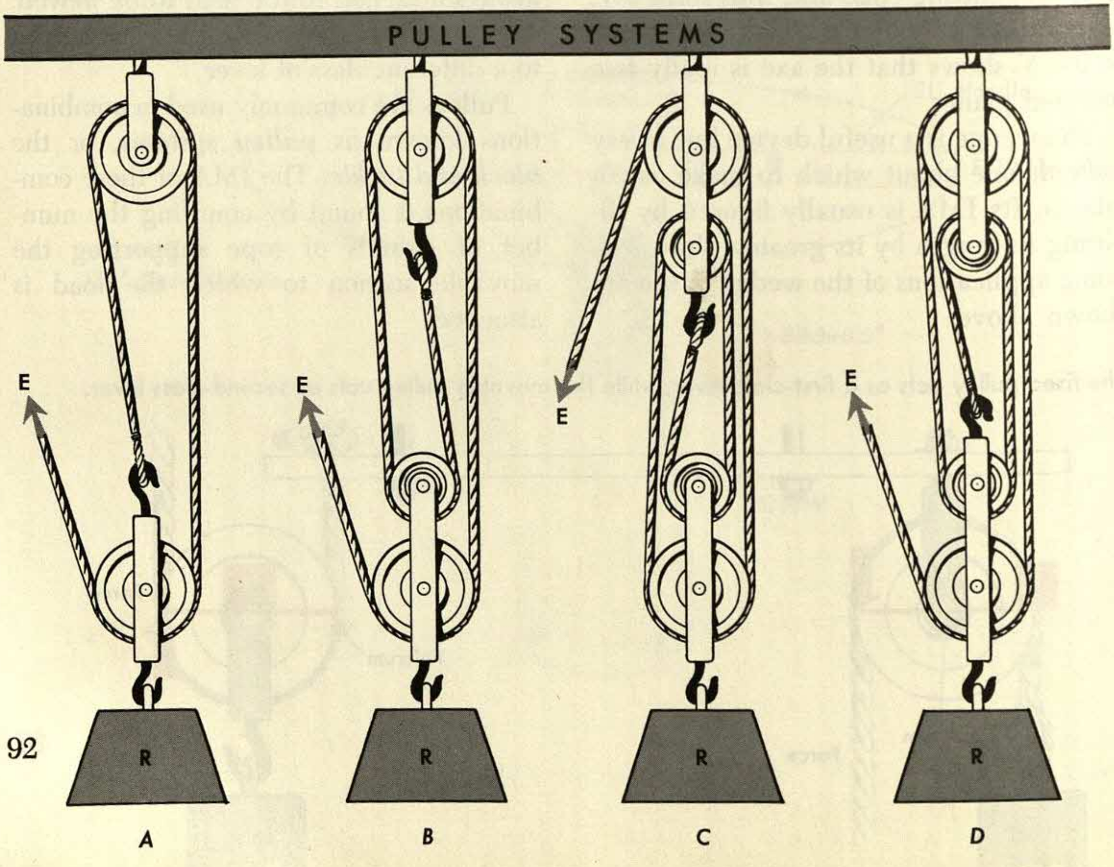
The fixed pulley acts as a first-class lever, while the movable pulley acts as second-class lever.



Many different pully systems are used in a power shovel.

Marion Power Shovel Co.

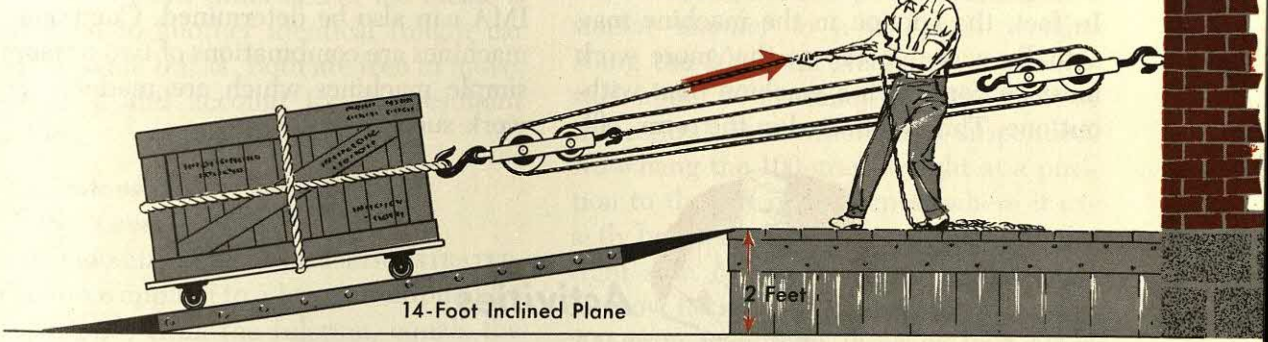
Four different pulley systems are shown below. How can you determine the IMA of each system?



COMPLEX OR COMPOUND MACHINES

When two or more simple machines are made to do work successively as shown in the diagram below, you have a *compound machine.* The overall IMA of such a machine is equal to the product of the individual IMAs of the simple machines involved. This machine has an IMA of 35 (7 for the inclined plane and 5 for the block and tackle).

COMPOUND MACHINE



Loading ramp, below, uses inclined plane and other simple machines to get cargo aboard.

United Air Lines

SUMMARY

Simple machines add to the ease and convenience with which work can be done by multiplying force, changing the direction of the action of the force, or by increasing the speed and the distance through which an applied force acts. However, simple machines do not save work. In fact, the friction in the machine may actually waste energy so that more work must be done with a machine than without one. This is reflected in the term "efficiency," which is the ratio of the work output to the work input. For any machine, the actual mechanical advantage (AMA) can be found by dividing the resistance by the effort, and the ideal mechanical advantage (IMA) by the ratio of the distance the effort moves to that which the resistance moves. Each type of simple machine has a special way by which its IMA can also be determined. Compound machines are combinations of two or more simple machines which are made to do work successively.

Activities

A. Testing Yourself

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. Simple machines cannot be used to (a) multiply force (b) change the direction of a force (c) save work (d) gain speed and distance.

2. When a lever has the force applied between the fulcrum and the load, the lever is a (a) first-class lever (b) second-class lever (c) third-class lever (d) fourth-class lever.

3. If a simple machine moves a load of 1,000 pounds with a force of 250 pounds, the mechanical advantage of the machine is (a) 0.25 (b) 4 (c) 250 (d) 1,000.

4. The relationship between the work obtained from a simple machine and the work put into the machine is known as (a) efficiency (b) mechanical advantage (c) work (d) energy.

5. Lubrication makes it possible for some machines to operate more efficiently by (a) reducing the load (b) increasing the friction (c) reducing the friction (d) decreasing the distance of the applied force.

6. The simple machine with the highest possible ideal mechanical advantage is the (a) lever (b) pulley (c) inclined plane (d) jack screw.

7. A force applied downward to the right of the fulcrum tends to cause a lever to turn (a) clockwise (b) counterclockwise (c) backwards (d) upwards.

8. The ratio of the effort applied to a machine to the resistance overcome is (a) the AMA (b) the IMA (c) the efficiency (d) none of these.

9. The distance the effort moves divided by the distance the resistance moves is the (a) the AMA (b) the IMA (c) the efficiency (d) none of these.

10. The IMA of a compound machine is found by doing the following to the IMA of the individual machines (a) adding (b) subtracting (c) multiplying (d) dividing.

B. Applying Your Knowledge

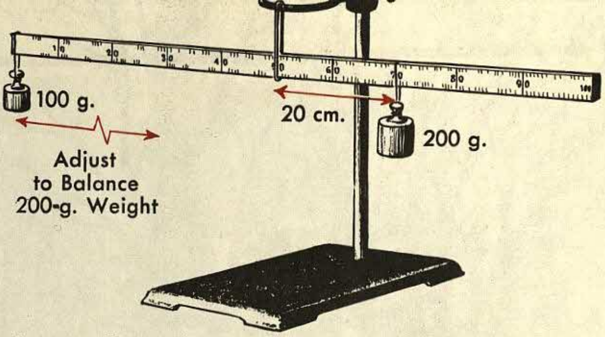
Assume the resistance of the pulley system in figure D on page 92 to be an empty freight car. The other end of the tackle is attached to another identical freight car on the same tracks. Both are free to move. Describe and account for the resultant motion.

C. Demonstrating the Law of the Lever

Generalization to Be Demonstrated. The force applied to a lever, multiplied by its distance from the fulcrum, equals the weight lifted by the lever, multiplied by its distance from the fulcrum.

What You Need. Meter stick; adjustable clamp to support meter stick; ringstand; two weights (100 grams and 200 grams); string.

What to Do. Attach clamp to center of meter stick and suspend it with a string from the ringstand so that the meter stick hangs parallel to the top of the table. If a clamp is not available, the meter stick can be supported by the string alone.



Tie one end of a piece of string to a 100-gram weight and form a loop with the other end so that it slips over the meter stick. Fasten another piece of string in a similar manner to a 200-gram weight. Hang the 200-gram weight on the meter stick about 20 centimeters to the right of the central point where it is suspended. Now hang the 100-gram weight at a position to the left of the center where it exactly balances the 200-gram weight on the right side. When this position is found, see how far it is from the center. Place the 200-gram weight in three or four other positions and again balance it with the 100-gram weight. Record your observations in a table like the one below.

What to Observe. How does the product recorded in Column 3 compare with that recorded in Column 6 in each case?

What Does It Mean? How do the results you obtained prove or disprove the generalization stated at the beginning?

A Basic Assumption in This Generalization. The measurements obtained in this demonstration are similar to those obtainable from any kind of lever.

Weight *(1)*	*Distance to Center (cm)* *(2)*	*Column 1 × Column 2* *(3)*	*Weight* *(4)*	*Distance to Center (cm)* *(5)*	*Column 4 × Column 5* *(6)*

Wide World

This four-passenger car is held up by a cushion of air, a gas. The air car can travel up to thirty-five miles an hour on this air cushion, which is from six to twelve inches in depth. Car is wheel-less.

PROBLEM 3: HOW ARE GASES USED TO DO WORK?

Gases can be used to do work. For centuries, man has used the winds—air in motion—to move his sailing ships across oceans and to turn his gristmills. He has learned to use the atmosphere to lift gas-filled aircraft. He has learned how to lift heavier-than-air aircraft by taking advantage of the physical and chemical characteristics of air. Not content with using the forces stemming from the natural motion and mass of gases, man has developed ways of compressing gases to make them do additional work.

WORK FROM ATMOSPHERIC PRESSURE

As you learned in Unit 2, gas pressure depends upon the density and kinetic energy of the gas molecules in a given space. The pressure is increased as the number of molecules in a given space increases, or as the size of the space in which the gas is confined decreases. The pressure may be decreased by removing molecules, or by increasing the space in which the same number exist. Furthermore, gases move from a place of high pressure to a place of lower pressure.

Work in Breathing

Man's chest cavity is connected to the outside air as shown in the diagram on this page. When the muscles enlarge the chest cavity around the lungs, the pressure in them is reduced. The greater pressure of the outside air then causes it to flow into the lungs. Work is done.

You exhale when the collapsing chest cavity crowds the air molecules together and forms a higher pressure than that of the outside air. Again work is done.

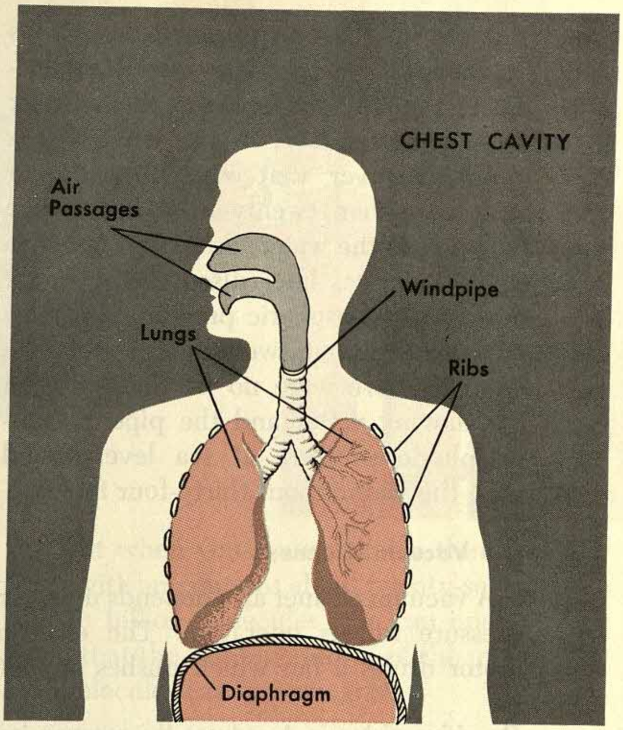
The Siphon

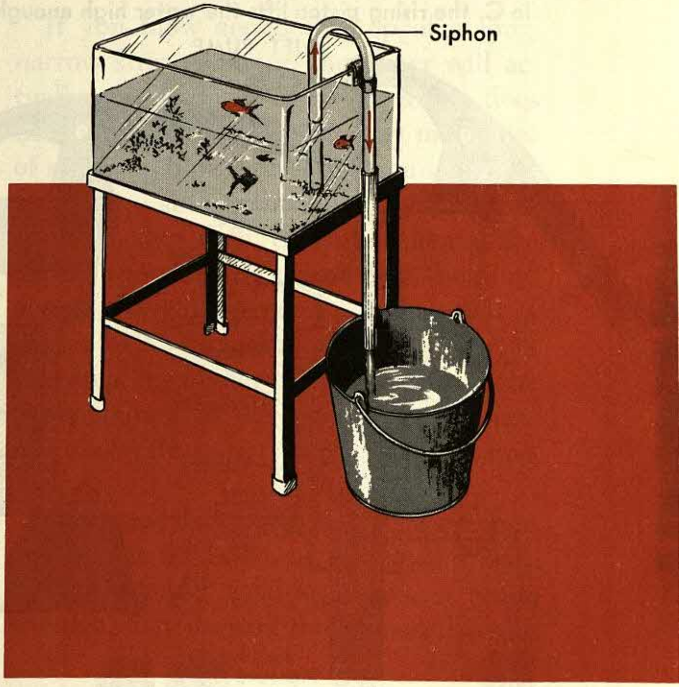
Sometimes it is necessary to remove water from a vessel such as a fishbowl without tipping the vessel. This can be done by using a ***siphon,*** a tube shaped like an inverted U, through which a liquid may be forced upward by air pressure and carried across to a lower level.

Siphons have many purposes. Where water has to be obtained from distant sources, large siphons may conduct it under rivers and over hills. Cream may be removed from bottled milk by use of siphons. In science laboratories, siphons are used to remove liquids from bottles easily and safely. In siphoning liquids that may be harmful to the body, one should never remove the air from the siphon by sucking.

The Lift Pump

A lift pump operates because of atmospheric pressure. How it makes use of atmospheric pressure can be learned from a study of the diagram on page 98.





When lift pumps were invented, it was thought that they would operate regardless of the distance between the cylinder and the water level in the well. It was found, however, that when the cylinder was more than twenty-eight feet above the level of the water, the pump failed to operate. It was later discovered that, at sea level, atmospheric pressure will raise water only about twenty-eight feet in a pipe. If there were no friction between the moving water and the pipe, the atmospheric pressure at sea level would raise the water about thirty-four feet.

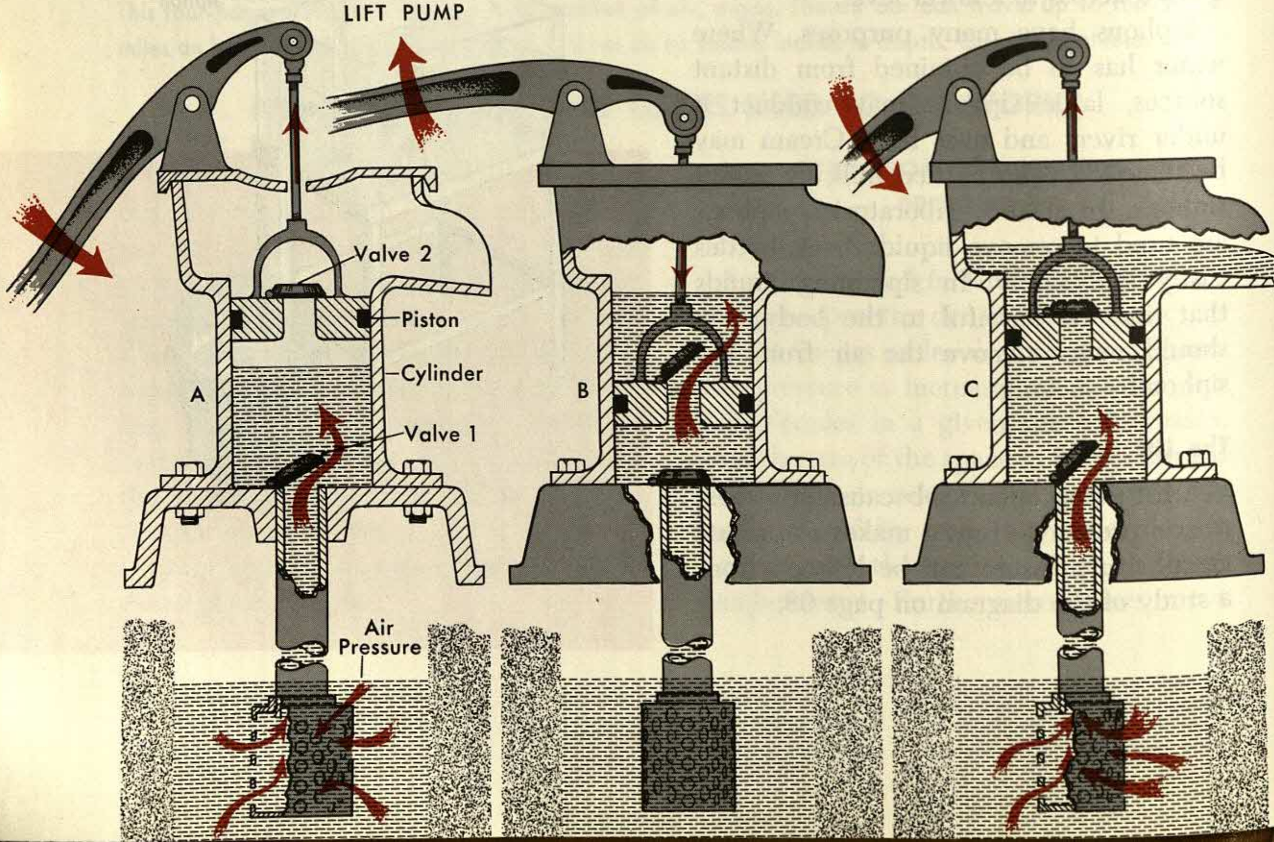
The Vacuum Cleaner

A vacuum cleaner also depends upon air pressure for its operation. The electric motor drives a fan which pushes air out of the vacuum cleaner. Because the number of molecules of air is reduced, an area of low pressure is created inside the cleaner. Since the air pressure on the outside of the cleaner is now higher than on the inside, air is pushed through the rug into the cleaner. As air passes through the rug, dust is carried with it into the cleaner.

Reducing Air Pressure

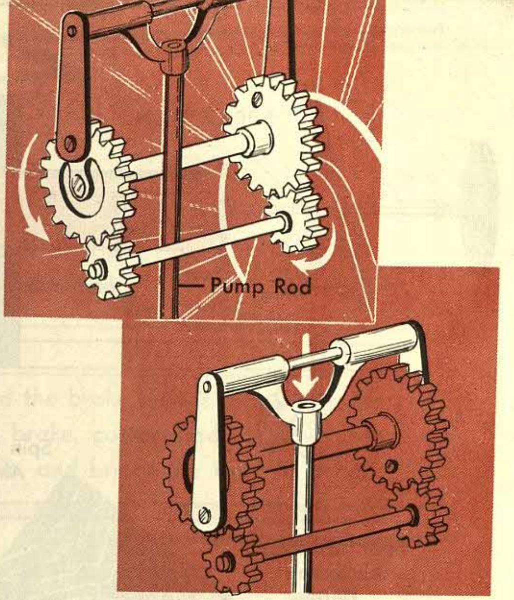
All devices operated by reducing air pressure use some means of decreasing the air pressure inside the device. When you drink soda, you reduce the air pressure in the straw by sucking on one end of it. In the lift pump, a piston sliding in a cylinder reduces the pressure. In the vacuum cleaner, a motor-driven fan reduces the pressure inside the cleaner.

The rising piston in A reduces the pressure inside the cylinder. Outside air pressure forces water up through the valve to fill the cylinder. In B, the piston descends. Water passes through valve 2. In C, the rising piston lifts the water high enough to permit the water to run out of the spout.



Standard Oil Co. (N. J.)

Energy of the wind turns the vanes of this mill, used to pump water. Gears are at right.



WORK FROM AIR IN MOTION

For centuries, man has depended almost entirely upon the direct push of moving air to do a variety of jobs for him. And in some rural areas in this country, this force is still used by the farmer. And with increasing knowledge of the movement of air, this force is used today to keep aloft gliders, balloons, and airplanes.

Kites and Windmills

In some localities, the windmills which pump water, grind grain, and even generate electricity, operate by the direct push of moving air.

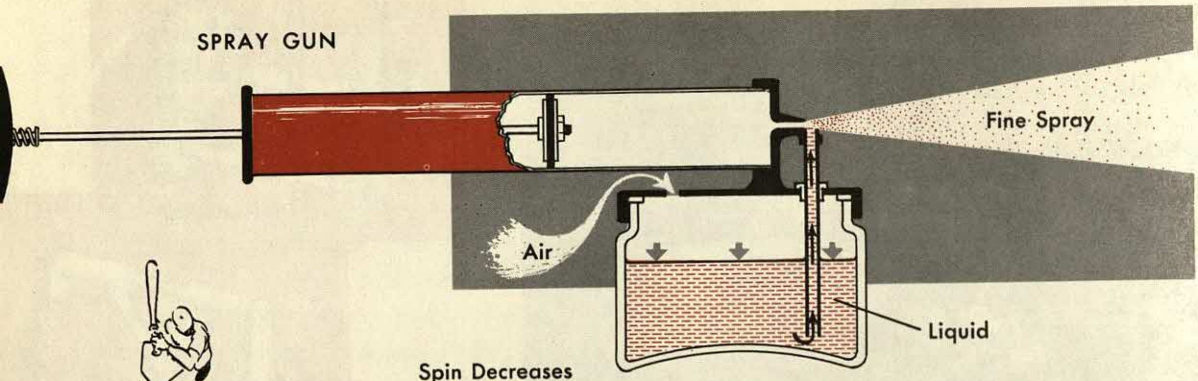
If you have ever flown a kite, you know that the kite will not fly unless the wind is blowing, or the kite is pulled rapidly through the air.

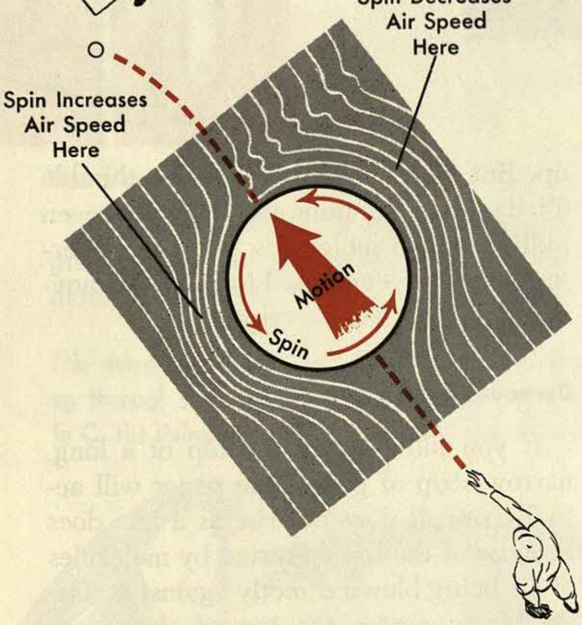
A kite is lifted into the air and held up in the air by the force produced when molecules of air hit the kite. Since each molecule of air weighs so little, it is difficult to understand how air molecules can produce enough force to hold the kite up. But when you realize that a thimble filled with air contains about twenty-seven million billion molecules, you can understand that the combined force of the moving molecules can be very great.

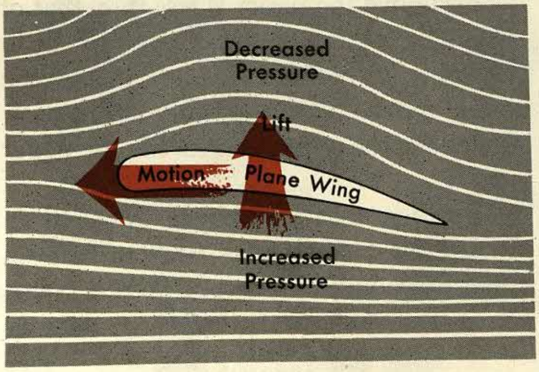
Bernoulli's Principle

If you blow across the top of a long, narrow strip of paper, the paper will actually rise. It does not rise as a kite does because of the force exerted by molecules of air being blown directly against it. The air blown across the top of the paper moves faster than the air beneath the paper. The sidewise pressure of the moving air above the paper is less than that of the air below the paper. Therefore air, in the area of higher pressure below the paper, moves to the area of lower pressure above the paper and carries the paper with it.

The idea that pressure is reduced in moving air is known as ***Bernoulli's principle.*** Bernoulli (bur-NOOL-ee), a Swiss scientist, first showed that, when the rate





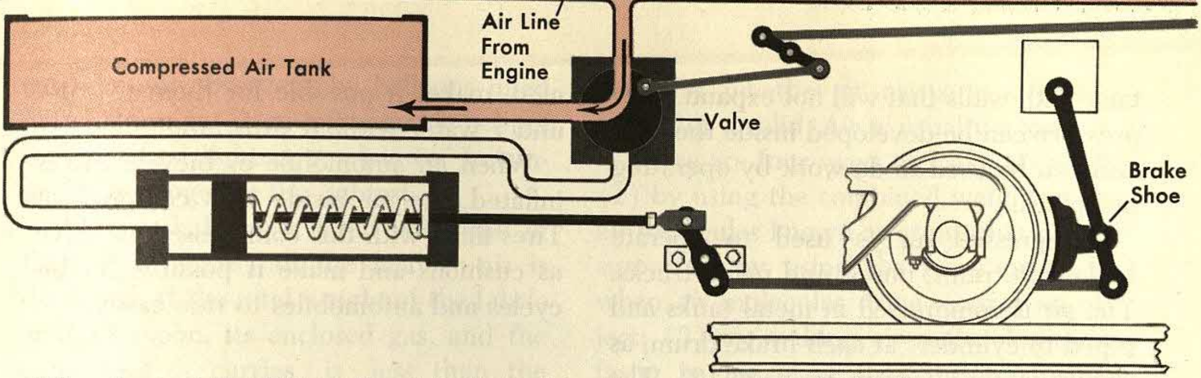


of flow of a fluid is increased, its sidewise pressure is decreased. The reverse is also true.

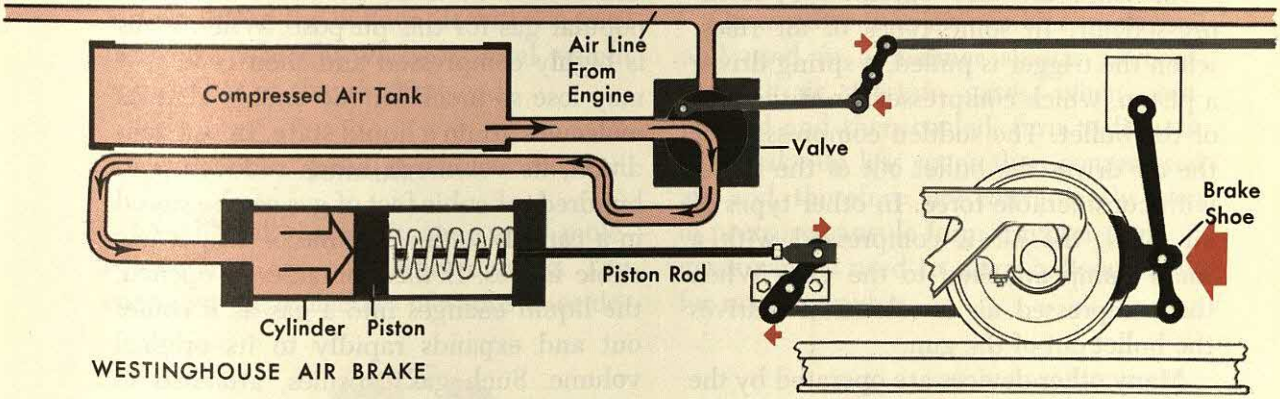
There are many common illustrations of Bernoulli's principle. The curve of a baseball, the cut of a tennis ball, and the slice of a golf ball are caused by the force resulting from a difference in air pressure. The difference is created when the air moves faster around one side of the ball than around the other as it spins.

Airplane Lift and Control

The *lift* of an airplane—that is, the force which holds the plane up—comes mainly from the difference in pressures between the air above the wing and the air below it. The air above the wing moves faster than the air below it because the wing is constructed in the shape of an ***airfoil.*** An airfoil is the surface of a plane such as a wing, stabilizer, or aileron designed for the purpose of lifting or controlling the plane by making use of surrounding air currents. By the use of an airfoil, the pressure above the wing is reduced and the normal air pressure pushes the wing upward.



When the brake is off (top), the air in the tank is compressed and the brake shoe is away from the wheels of the train. When the valve is turned on to apply the brake, compressed air flows into the cylinder, forces the brake shoe against the wheel of the train, and brings the train to a halt.



WESTINGHOUSE AIR BRAKE

The diagram on page 100 shows one type of airfoil. Although the difference in air pressure produces most of the lift of an airplane, some lift is obtained by the force of the air molecules striking the lower surface of the wing.

Compressed Air

Almost everyone has blown up a toy balloon. As air is forced inside, the balloon expands. How do the molecules of air furnish enough force to cause the balloon to expand?

To answer this question you can use the kinetic theory of matter. You have seen that air molecules are always in motion. Thus, billions of them are constantly bombarding the walls of the balloon and exerting pressure against them. If the number of molecules inside the balloon were increased, the pressure against the inside of the balloon would be increased, because more molecules would be hitting the balloon at every instant. The air molecules you blow into the balloon increase the pressure inside. Since the balloon is rubber, it expands. It will stay expanded so long as the additional air molecules remain inside and bombard the sides of the balloon at the same velocity.

When air is pushed into a container which cannot expand, the air becomes ***compressed*** inside the container. By pumping, or ***compressing,*** air into a steel tank with walls that will not expand, high pressure can be developed inside the tank and can be used to do work by operating machines.

Compressed air is used to operate brakes on trains, buses, and many trucks. The air is compressed in metal tanks and piped to cylinders at each brake drum, as shown in the diagram on page 101. The air brake is one of the most effective brakes for large vehicles.

Air rifles are also operated by compressed air. In some types of air rifles, when the trigger is pulled, a spring drives a piston, which compresses air at the rear of the bullet. The sudden compression of the air drives the bullet out of the barrel with considerable force. In other types of air rifles, the air is compressed with a small pump attached to the gun. When the compressed air is released, it drives the bullet out of the gun.

Many other devices are operated by the use of compressed air. Air hammers and air drills are valuable tools, some of them operating as rapidly as 20,000 blows per minute. Compressed air is also used to transport containers holding money and written messages through metal tubes to their destination.

Other Uses of Compressed Air

You may have wondered how it is possible for the men building supports for bridges to work under water. They can do so because they work in a ***caisson,*** a large, thick-walled, hollow pipe which is lowered into the water. Air is pumped into it until the air pressure is great enough to keep the water out. The caisson, large enough to accommodate several men, makes it possible for them to work under water without drowning.

When an automobile or bicycle tire is inflated, the air inside it is compressed. Tires filled with this compressed air serve as cushions and make it possible for bicycles and automobiles to ride easily.

CO_2 CAPSULES

Gases other than air may be compressed and used to do work. Carbon dioxide is a popular gas for this purpose. When a gas is highly compressed and then cooled, it may lose so much kinetic energy that its molecules attain a liquid state. In this condition, its volume is much reduced, and hundreds of cubic feet of gas can be stored in a capsule with a volume of only a few cubic inches. If this container is opened, the liquid changes into a gas as it comes out and expands rapidly to its original volume. Such gas capsules, attached to rubber life rafts, can be used to inflate the rafts in a matter of seconds when needed. Some toys are jet-propelled with such capsules. Some air rifles and pistols are fired in this manner.

HELIUM AND HYDROGEN

Balloons, blimps, and zeppelins, which weigh hundreds of pounds, have been built, yet they can rise to great altitudes. They are lifted from the ground by the ***buoyant force*** of the atmosphere. The buoyant force is equal to the weight of air it would take to fill the balloon.

Heavy astronomical instruments have been lifted into the upper atmosphere, above the dust and vapors that hinder earth-bound observers, by balloons filled with helium gas. Non-inflammable helium is the second lightest gas known. Inflammable hydrogen is the lightest.

When a balloon is filled with one of these light gases, all the heavier air is displaced. If the total weight of the fabric of the balloon, its enclosed gas, and the equipment it carries is less than the weight of air it would take to fill the balloon, it will rise. The difference between these weights is the amount of buoyancy left for lifting the balloon. It will rise until it reaches a height where its total weight equals that of the air displaced.

SUMMARY

Gas, like all matter, is made up of molecules which are constantly moving. The energy of the molecules of a substance determines whether it exists as a gas, a liquid, or a solid. Air is usually a gas.

There are four ways to make air work: (1) by using the combined weight of the air molecules known as atmospheric pressure; (2) by using the force produced when air molecules drive against an object; (3) by making air molecules move faster in one place than they do in another and thus cause differences in air pressure; (4) by compressing air through forcing more molecules into a container.

Gases other than air can be compressed and used in a manner similar to compressed air. Certain gases, when compressed and then cooled, turn to liquids. They take up less space than compressed air, and, therefore, are conveniently used in pressure-capsule form. Lighter-than-air gases can be used to carry balloons aloft for many purposes.

Activities

A. *Testing Yourself*

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. Man is able to breathe because (a) the lungs can suck air in and blow it out (b) of differences in air pressure inside of and outside of the lungs (c) his body needs oxygen (d) air is a mixture of gases.

2. In drawing water from a well by a lift pump (a) the water is lifted up by the handle of the pump (b) the pump forces air into the water, thus forcing it up (c) air pressure inside the pump becomes less than the pressure on the water in the well (d) the valves suck up the water.

3. If you blow across the top of a long strip of paper, the paper will rise because (a) air is also blown up underneath it (b) the pressure of moving air above the paper is less than that of the air below the paper (c) the moving air above the paper pulls the paper up (d) paper is lighter than air.

4. Air is doing work whenever it is used as a force to (a) hold objects in place (b) move objects (c) dry clothes (d) heat houses in cold weather.

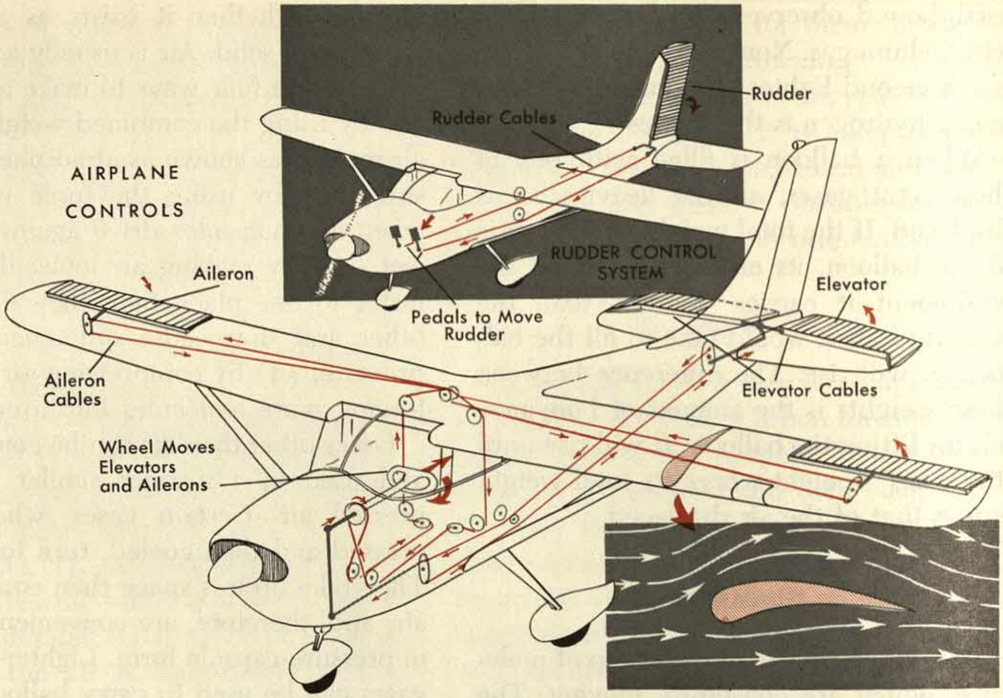


Diagram above shows how an airplane is controlled. When the pilot moves the wheel, he can make the plane go up or down, to the left or right. In this way, he can climb and glide, bank or turn, by moving different parts of the plane's surface.

5. Air becomes compressed when (a) the molecules of air are forced closer together (b) the wind stops blowing (c) air is held in a closed container (d) the molecules of air stick together.

6. Gas pressure in a container can be decreased by (a) decreasing the size of the container (b) decreasing the number of molecules of gas in the container (d) increasing the number of molecules in the container (d) none of these.

7. When a pilot moves the rudder control, the airplane turns because (a) the rudder pushed it (b) air turned it (c) the engine turned it (d) of Bernoulli's principle about the pressure of moving air.

B. Performing Experiments

Plan and conduct experiments to answer the following questions. You may think that you know what the answer is to each. This is your hypothesis. You do the experiment to test your hypothesis.

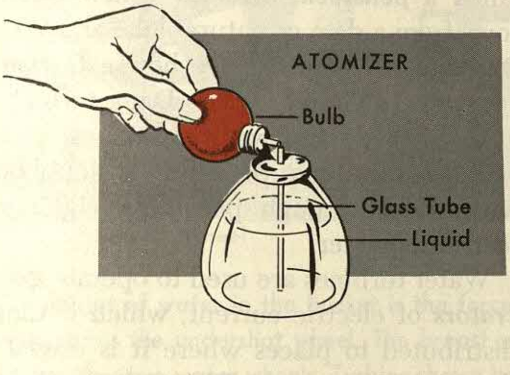
1. How does the diameter of a siphon tube affect the rate at which water can be removed from a container? Are they related in ways which can be expressed mathematically?

2. Why is it difficult to pour liquid from a can which has only one small hole in it?

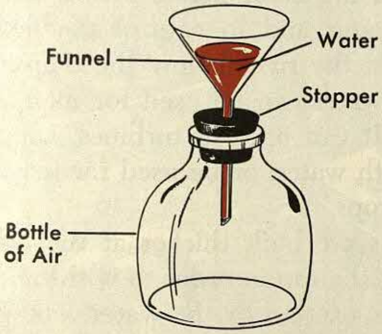
3. Why is it sometimes difficult to close the door on a car when all the car windows are closed?

C. Giving Explanations

1. What will happen when air is pumped through the atomizer shown below? Why?

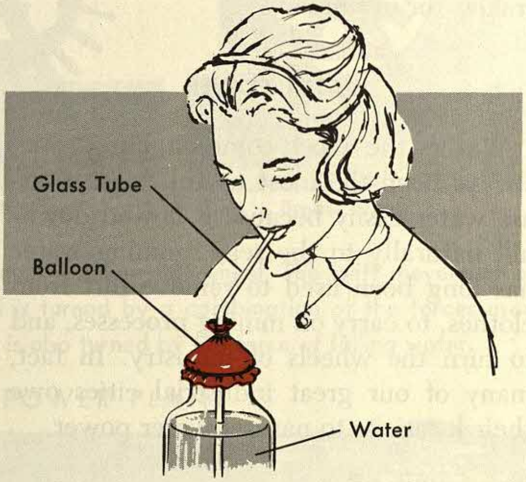


2. Why doesn't the water run into a bottle under conditions such as those shown in the diagram below?



3. How are the ailerons, rudder, and elevator used to control the flight of an airplane? See diagram on page 104.

4. How can the girl in the picture below get the water out of the bottle?

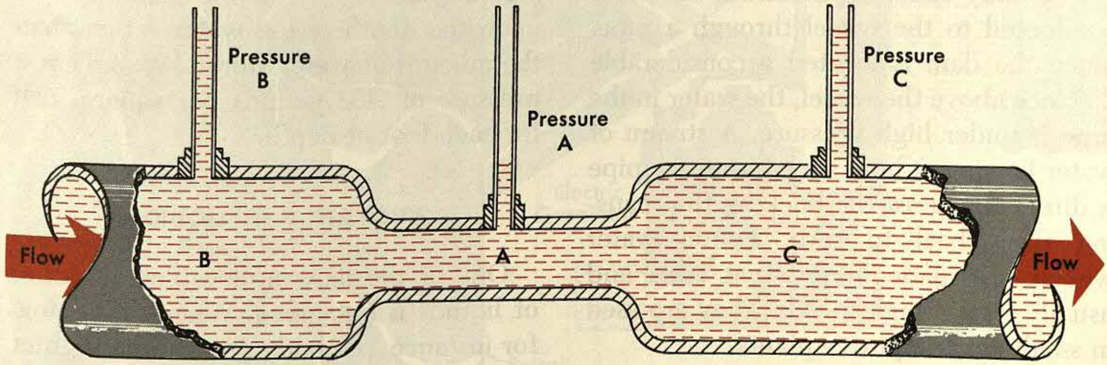


5. The diagram below shows a fluid, such as air or water, passing through a pipe.

a. In which part of the pipe is the velocity highest? Why?

b. How does the sidewise pressure at A compare with that at B and at C?

c. How does this diagram illustrate Bernoulli's principle?



PROBLEM 4: HOW ARE LIQUIDS USED TO DO WORK?

Liquids are also used by man to help him do his work. Liquids that do not freeze as easily as water are more valuable in certain power applications—hydraulic brakes, for example.

WATER POWER

Water, the most common liquid, has always been the most useful. Man could use water easily because it flowed downhill naturally to the sea. Running water has long been used to remove dirt from clothes, to carry on mining processes, and to turn the wheels of industry. In fact, many of our great industrial cities owe their locations to natural water power.

Water Wheels

Three types of water wheel—the ***overshot,*** the ***undershot,*** and the ***breast***—were widely used at one time. The way they operated is shown on page 107. These wheels have been largely replaced by the ***Pelton*** and ***turbine*** types.

The Pelton water wheel is a metal water wheel with cup-shaped buckets built around the rim. The water which turns it is usually collected behind a dam and conducted to the wheel through a pipe. Since the dam is located a considerable distance above the wheel, the water in the pipe is under high pressure. A stream of water flowing at high speed from the pipe is directed against the buckets, thus causing the wheel to turn. Pelton water wheels are made in different sizes and usually turn at high speeds. They are used in small electric-power plants.

The turbine makes the best possible use of the force of running water. It is situated at the lower end of a large pipe called a ***penstock,*** through which water flows from a dam or natural lake above it. On page 107, you can see how a turbine operates. In Grand Coulee Dam, turbines fifty feet wide and weighing almost one-and-a-half million pounds are supplied with water through penstocks eighteen feet in diameter.

Water turbines are used to operate ***generators*** of electric current, which is then distributed to places where it is used to do productive work. Electricity will be studied in Unit 5.

Dam Construction

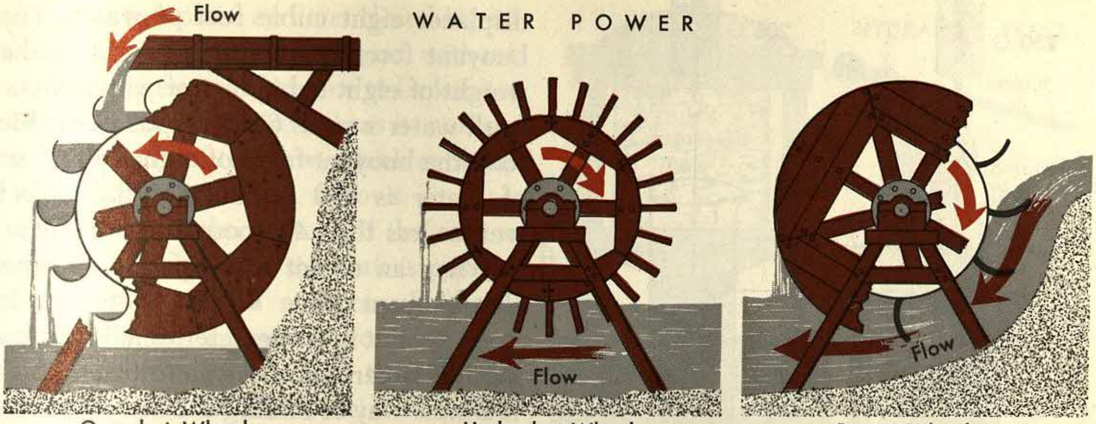
Dams are built across rivers both to store water and to control the flow of water in the river below the dams. The stored water can be used for many purposes. It can operate turbines, supply a city with water, or be used for irrigating farm crops.

Dams are built thicker at the bottom than at the top in order to withstand the pressure exerted by the water. The water pressure at the base of the dam depends upon the depth of the water rather than the amount of water stored. Water has a pressure of .433 pounds per square inch for each foot of depth.

BUOYANCY IN LIQUIDS

One of the most noticeable properties of liquids is ***buoyancy.*** When swimming, for instance, the body seems to be lighter

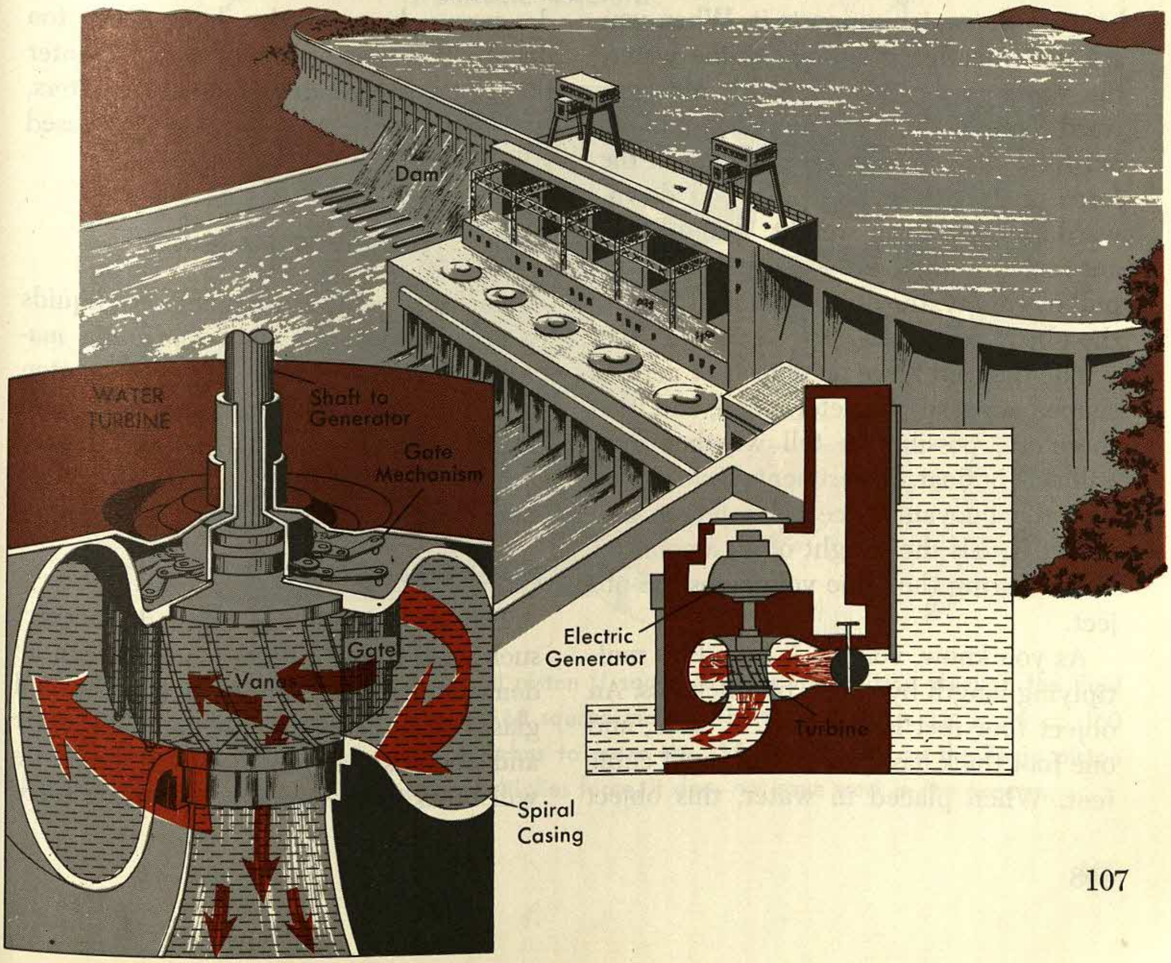
WATER POWER

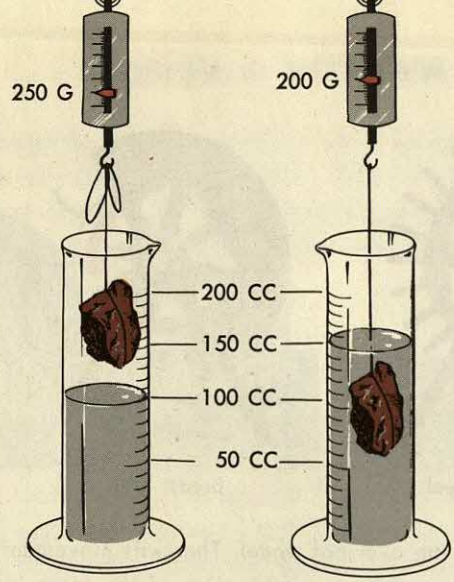


Overshot Wheel Undershot Wheel Breast Wheel

The weight of water in the bucket is the force turning the overshot wheel. The swift movement of water turns the undershot wheel. The breast wheel is turned by a combination of the forces used in the other two water wheels. Turbine shown below is also turned by the force of falling water.

ELECTRIC POWER PLANT





The water rises 55 cc. when the rock is lowered into it. What is the buoyant force of the water?

because the water supports it. When you are underneath the surface of the water, the water pushes you upward. This upward force of the water is called a ***buoyant force,*** or buoyancy. It acts against the force of gravity, which pulls you downward and gives you weight. If the buoyant force on an object is greater than the pull of gravity, the object will float; if less, the object will sink.

The buoyant force on objects of certain shapes can easily be determined, and it is, therefore, possible to tell whether they will sink or float. Experiments have shown that the buoyant force of water on any object equals the weight of an amount of water having the same volume as the object.

As you know, volume is found by multiplying length by width by thickness. An object four feet long, two feet wide, and one foot thick has a volume of eight cubic feet. When placed in water, this object displaces eight cubic feet of water. The buoyant force is, therefore, equal to the weight of eight cubic feet of water. Since fresh water weighs 62.4 pounds per cubic foot, the buoyant force of eight cubic feet of water is 499 pounds. If the object weighs less than 499 pounds, it will float.

When an object is irregular in shape, the buoyant force which water would exert upon it must be determined by some method other than the one just described. A simple way of finding the buoyant force of water on irregularly shaped objects is shown at left.

When a boat is put into water, it sinks until the weight of the water which it displaces equals the weight of the boat and its load. Overloading a small boat is dangerous because the boat sinks too deeply. It is then easier for water to enter the boat over the sides. Once water enters, the weight in the boat has been increased still further, and the boat may sink.

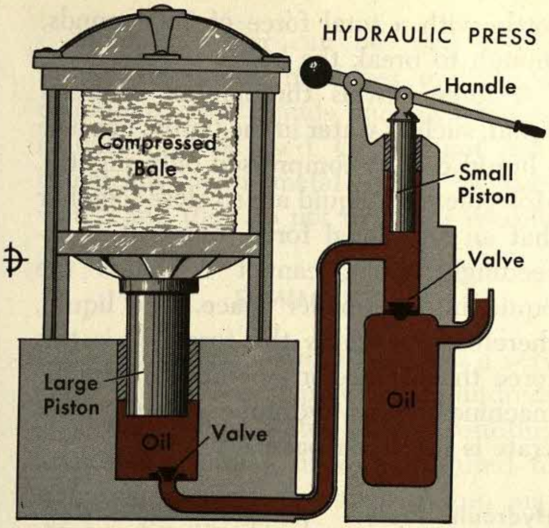
HYDRAULIC MACHINES

Machines which use enclosed liquids to exert force are called ***hydraulic machines.*** They are used for pressing cotton into bales, punching holes in steel, and lifting heavy weights. Barber and dentist chairs often are operated by hydraulic machines.

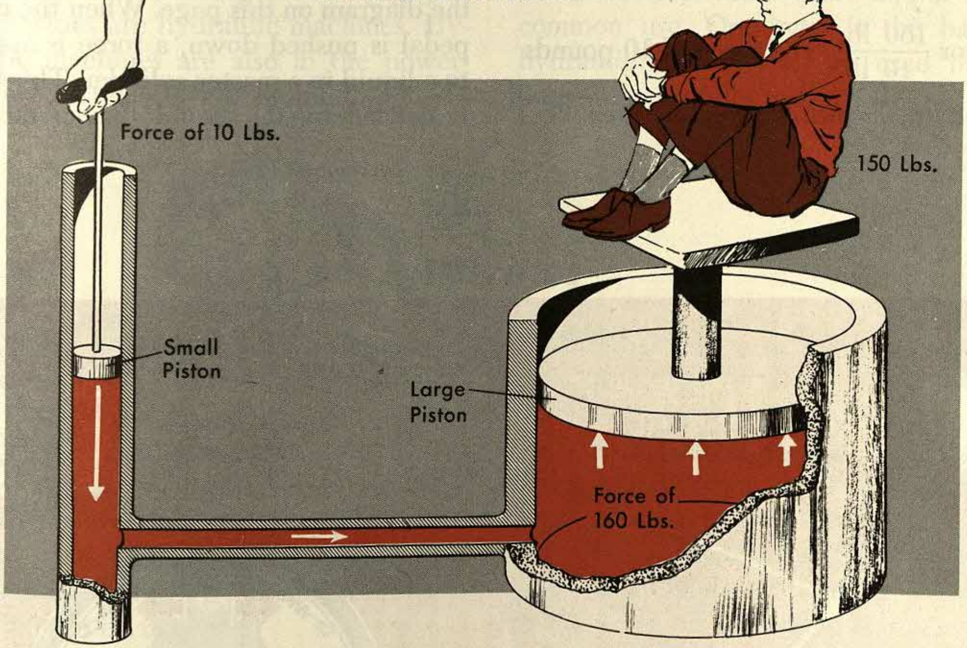
Pascal's Law

The way liquids can be made to exert such great force in these machines can be demonstrated very simply. If a thin-walled glass bottle is completely filled with water and a cork is then forced into it, the bottle will break. This happens because a force applied at one place on an enclosed liquid is conducted through the liquid without loss. This statement has come to be known as ***Pascal's Law*** because he was its author. An application of this law, which explains the breaking of a bottle, follows.

If the area of the bottom of the cork is one square inch and if the cork is pushed into the bottle with a force of fifteen pounds, the fifteen-pound force is sent from the bottom of the cork through the water to all parts of the bottle. This means that the water pushes against the walls of the bottle with a force of fifteen pounds on every square inch. If the surface of the inside of the bottle is fifty square inches, the water pushes against the inside of the


HYDRAULIC PRESS

HYDRAULIC MACHINE



A force of 10 pounds exerted by the small piston (1 square inch) is transmitted through the fluid to each square inch of the large piston (160 square inches). The total force is 16 × 10 = 160 pounds. The small piston must move 16 inches to move the 150 pound man on the large piston 1 inch. Although this hydraulic machine multiplies force, it does not save work in the process.

bottle with a total force of 750 pounds, enough to break the bottle.

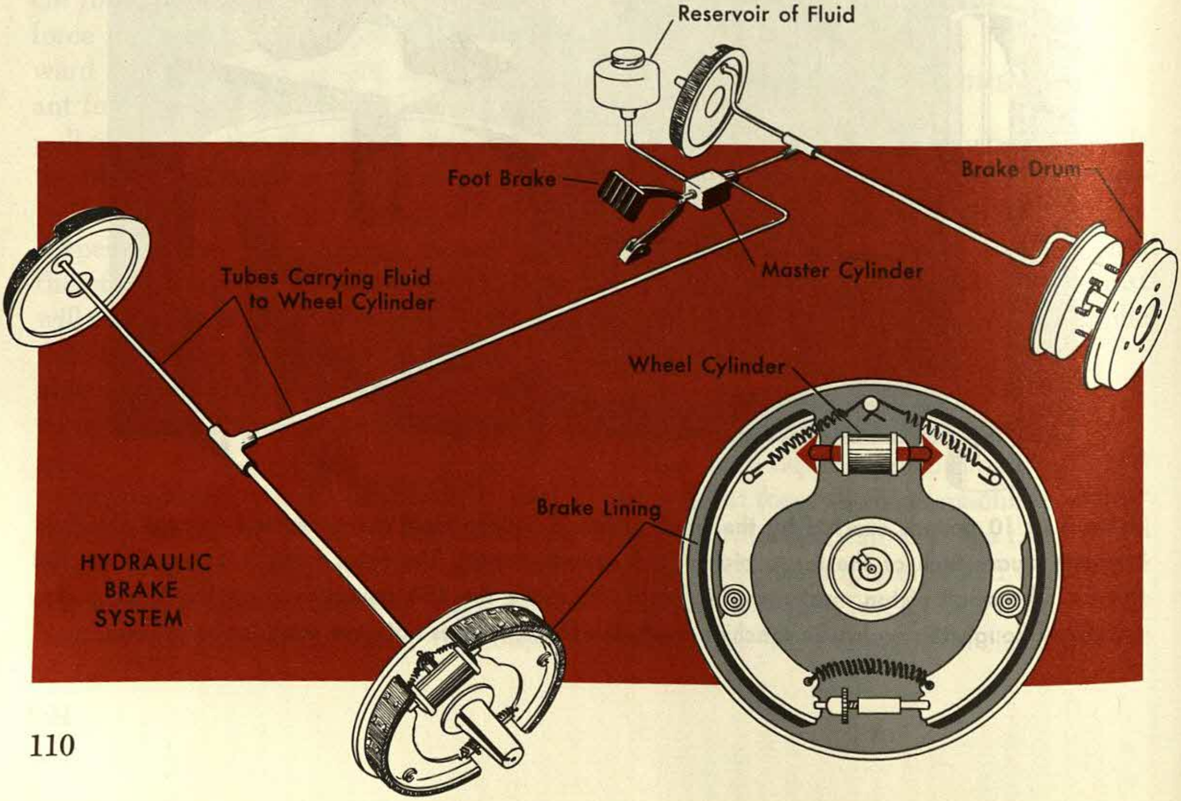
A force travels through an enclosed liquid, such as water in the bottle, because a liquid can be compressed only slightly. Molecules of a liquid are so close together that an additional force, unless it is exceedingly great, cannot compress the liquid into a smaller space. The liquid, therefore, transmits the force. It is this force that is used in operating hydraulic machines. How hydraulic machines operate is shown on page 109.

Hydraulic Press

The actual mechanical advantage of a hydraulic machine is found by the ratio of R to E. In the example on page 109, it is 15, or $\frac{150 \text{ lb.}}{10 \text{ lb.}}$. The force of 10 pounds on the small piston with an area of 1 square inch causes a pressure of 10 pounds per square inch on the enclosed hydraulic fluid. As Pascal discovered, this pressure is transmitted to each of the 16 square inches of the large piston supporting the man. This should give a total upward force of 160 pounds on the piston. Obviously some force was wasted in overcoming the friction of the tight-fitting pistons against the cylinder walls. The IMA is 16, but the AMA is only 15. Can you figure the efficiency from this? The work input can be seen to be 160 inch-pounds, compared to the 150 inch-pound output. Does this give the same efficiency?

Hydraulic Brakes

Hydraulic brakes operate as shown in the diagram on this page. When the brake pedal is pushed down, a force is applied to a liquid in a master cylinder. This force is carried by the liquid throughout the



braking system, and is applied to a piston in another cylinder at each wheel. The piston at the wheel cylinder applies the brake. Hydraulic brakes are used on most automobiles because they make it possible to get the same braking force at each wheel simultaneously.

Other Uses of Hydraulic Machines

Hydraulic machines are used for many purposes. Barber and dentist chairs, for example, are supported on the large piston of a hydraulic machine. To raise the chair, the operator applies a force to a small piston by pumping a lever.

Automobile lifts at service stations, elevators in some buildings, and the devices for raising and lowering the landing gear on airplanes are hydraulic machines. Hydraulic machines are also in the power-steering systems of automobiles.

Although water can be used as the liquid in hydraulic machines, under most conditions other liquids, such as mixtures of oils, must be used. Oils do not react chemically with metal parts, as does water, and they do not freeze as readily.

SUMMARY

Natural running water has been a very important source of power for hundreds of years. Today water power resulting from the damming of water is used to make electricity rather than to run machinery directly. The buoyant property of water has allowed heavy cargoes to be transported easily. Hydraulic machinery using water or some other liquids are in common use. One type is the basis of hydraulic brakes that are used in passenger automobiles today.

Activities

A. Testing Yourself

Select the ending which best completes each statement and write the letter in the proper place on your answer sheet.

1. Water power from the natural flow of water over the ground is made possible by the earth's (a) spherical shape (b) gravitational force (c) seasonal changes (d) rotation on its axis.

2. An object that displaces 4 cubic feet of water when placed in a lake will float if it (a) weighs more than 4 cubic feet of water (b) weighs less than 4 cubic feet of iron (c) weighs less than 4 cubic feet of water (d) is completely watertight.

3. The pressure of water against the base of a dam depends upon the (a) source of water (b) amount of water backed up behind the dam (c) rate at which water flows out of the dam (d) depth of water behind the dam.

4. The fact that a force applied at one place on an enclosed liquid is conducted to all parts of the liquid is called (a) Pascal's Law (b) Bernoulli's principle (c) hydraulic pressure (d) buoyancy.

5. In the United States, most water power is used to (a) turn overshot water wheels (b) fill up reservoirs (c) produce electric power (d) run machinery directly.

6. If a water wheel is so mounted that paddles along its rim dip into a stream of moving water, the wheel is known as (a) overshot (b) undershot (c) breast (d) Pelton.

7. The wheel most widely employed for using water power is (a) breast (b) Pelton (c) water turbine (d) overshot.

8. If water produces a pressure of .433 pounds per square inch for each foot of depth, the pressure per square inch at a depth of 20 feet would be (a) 0.866 (b) 8.66 (c) 86.6 (d) 0.216.

9. If an object weighing 50 pounds and displacing 49 pounds of water were thrown into a lake the object would (a) float (b) sink part way to the bottom of the lake (c) sink to the bottom of the lake only if the lake were very shallow (d) sink to the bottom of the lake regardless of its depth.

B. Conducting a Demonstration

GENERALIZATION TO BE DEMONSTRATED. The apparent loss of weight of bodies placed in water is equal to the weight of the water they displace.

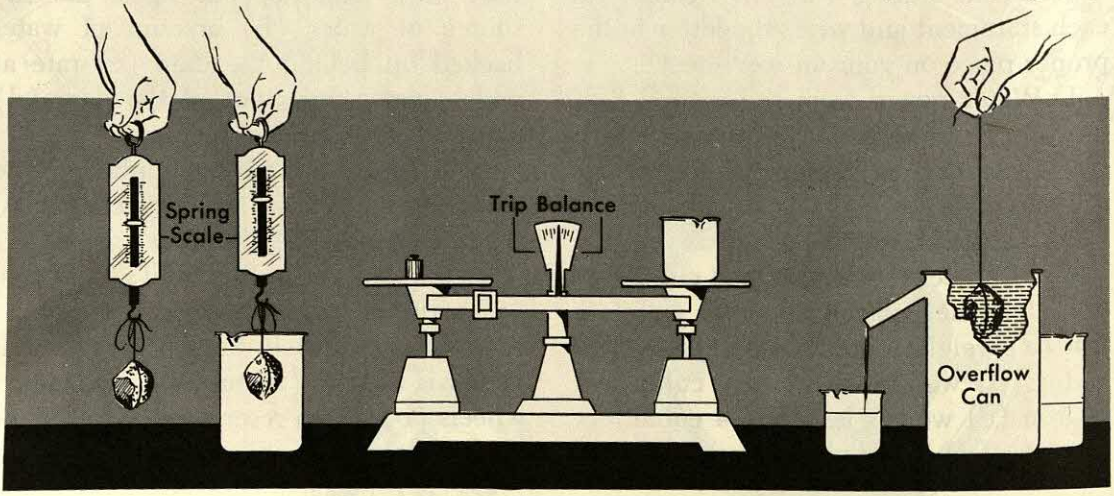
WHAT YOU NEED. A trip balance; a piece of string; a small rock; an overflow can or large beaker; a small beaker; some water; a spring scale.

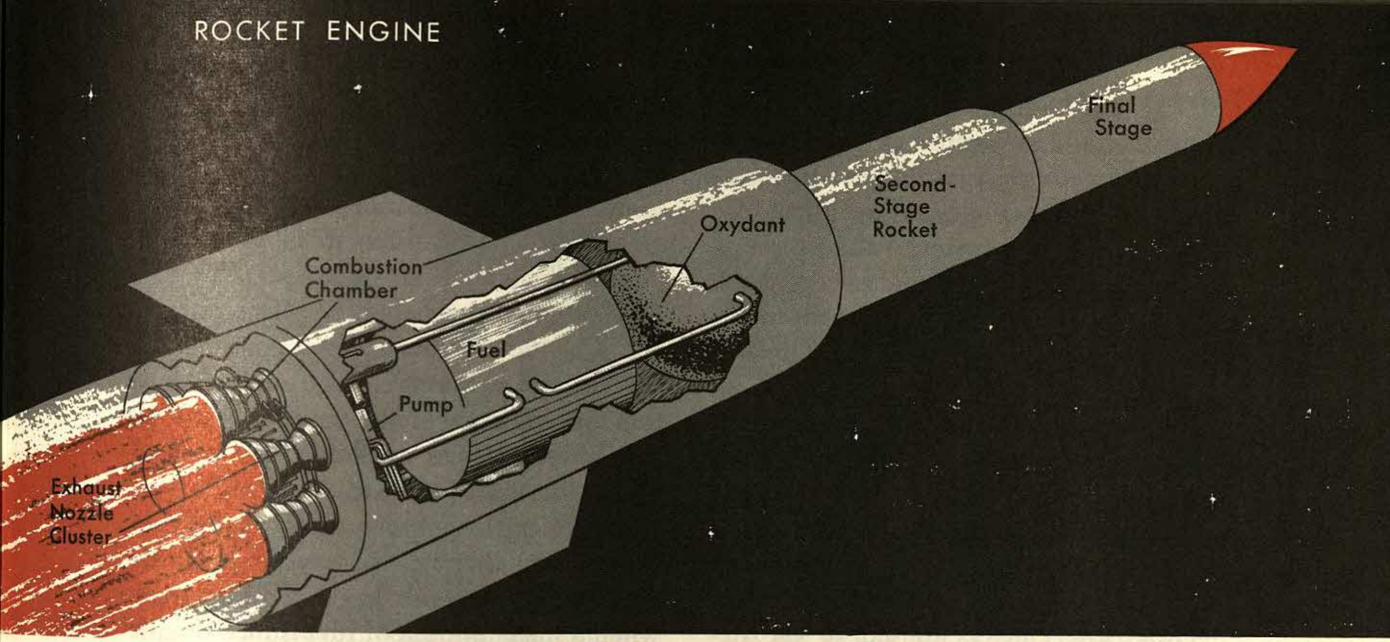
WHAT TO DO. Using the spring scale, find the difference between the weight of the rock in and out of water. Make a record of this difference.

Weigh the small beaker empty on trip balance and record its weight. Place the overflow can on a level table and pour in water until it overflows. Catch the overflow in the large beaker. When water stops running out of the overflow can, place the small beaker under the spout. Carefully lower the rock into the overflow can filled with water. When no more water runs out of this container, again weigh the small beaker and the water that has run into it. Subtract the weight of the empty beaker from the total weight of the beaker and water.

WHAT TO OBSERVE. How does the weight of the water displaced by the rock compare with the weight lost by the rock when it was placed in water?

WHAT DOES IT MEAN? On the basis of your observations in this demonstration, would you be willing to accept the generalization for the above demonstration? State your reasons and your assumptions.




ROCKET ENGINE

PROBLEM 5: HOW ARE ENGINES USED TO PRODUCE POWER?

Although man still uses simple machines, he has learned how to build more complex ones that will do more work. To operate these machines requires more force than can be obtained conveniently from man or animals, so machines are built to use energy rapidly and to develop the large forces needed for transportation and for industry, agriculture, and many other activities.

When man uses simple machines, he usually operates them by the force of his muscles. The kinetic energy of running water develops the force needed to produce electricity in the large hydroelectric power plants. The force produced by an automobile engine, which drives the automobile, is developed from the chemical energy of the fuel the engine uses. Diesel engines in railroad locomotives develop the force for pulling the train from the kinetic energy of the molecules of gas. These, in turn, receive their energy from the chemical energy in the fuel burned.

ENGINES

Engines, sometimes called motors, are the devices used to develop force from energy. There are gasoline and steam engines, atomic and jet engines; electric motors, automobile motors, and airplane motors. The primary purpose of engines is to develop the force to do work from some type of energy.

You have learned that the oxidation of fuel releases heat energy, and that heat energy can do work. Through the years, various types of engines have been made to convert heat energy into the force necessary to operate large, complex machines in use today.

Steam Engines

One of the first engines ever made was the ***reciprocating steam engine.*** Reciprocating means moving back and forth. Although such a movement of the piston of an engine is most wasteful of energy, various types of this engine were the main source of mechanical power for nearly two centuries.

The first steam engines were used to operate pumps to keep coal mines from flooding. Their probable efficiency was less than five percent. The latest reciprocating steam locomotive can achieve only ten to fifteen percent efficiency.

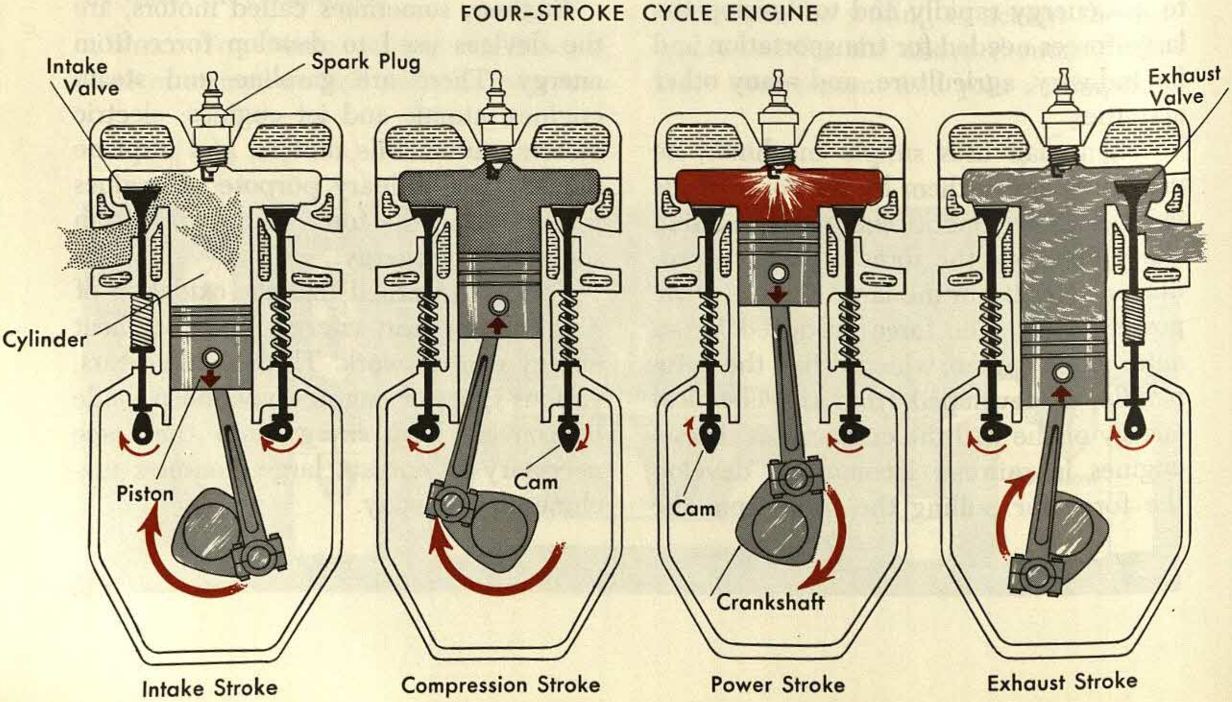
These low efficiencies led to the development and use of the more efficient ***internal combustion engine.*** Whereas the fuel for the steam engine was burned in a boiler separate from the engine, the fuel for this new type engine burned within the engine, thus giving it its name.

Gasoline Engines

Three reasons for the rapid rise in popularity of the gasoline engine, the most common of the internal combustion engines were: (1) these engines had a higher efficiency than steam engines; (2) they weighed much less per horsepower; and (3) the efficiency of a small engine was as good as that of a large engine. Now that an engine which could be used in small vehicles was available, automotive transportation became a reality.

The operation of a gasoline engine, as well as any other type of internal combustion engine, depends upon the fact that, when a small amount of fuel is mixed with a larger amount of air, a substance is produced that will burn very rapidly. In the gasoline engine, the fuel is mixed with air in a device called a ***carburetor,*** and the mixture is then burned rapidly in the cylinders. As it burns, a large amount of heat

A mixture of gaseous fuel and air enters the cylinder during intake stroke. The mixture is highly compressed during the compression stroke. A spark ignites the fuel and heat expands the gases. The piston is driven down to form the power stroke. Burned gases are forced out in the exhaust stroke.



is produced, which causes the remaining gases to expand. The expanding gases produce the force which moves the piston in the cylinder. The movement of the piston then makes it possible for the engine to run machinery and do work.

Although gasoline engines usually have more than one cylinder, each cylinder operates in the manner shown on page 114. Since it requires four strokes of a piston to complete the cycle of operation, this type of engine is called a ***four-stroke cycle engine.*** A great many gasoline engines, including those in most automobiles, trucks, and tractors, are four-stroke cycle engines. However, some smaller engines, such as those used in outboard motors and motor bicycles, are two-stroke cycle engines.

Diesel Engines

In a gasoline engine, an electric spark ignites the fuel in the cylinder. In the Diesel engine, however, the air taken into the cylinder on the intake stroke is compressed so highly that the heat energy from the work of compression raises its temperature to around 1000°F. At the beginning of the power stroke, fuel oil is ***injected***, or sprayed, under high pressure, into the hot air, where it automatically ignites and burns with explosive power. If only a little power is needed, a short squirt of oil is given. If greater power is desired, oil is injected for a greater portion of the power stroke. In this engine, neither a carburetor nor an electrical system is required. Otherwise, the Diesel engine is quite similar to the gasoline engine. Diesel engines can be operated on a low-grade fuel that costs less than gasoline.

Diesel engines are often used in large stationary power plants, in some buses and large trucks, and in some ships and railroad locomotives. Many times the Diesel engine is used to run an electric generator, which powers an electric motor. The motor moves the ship or locomotive.

Both Diesel and gasoline engines have the disadvantage of being reciprocating engines, with the attendant waste of energy. However, the Diesel has a higher efficiency than the gasoline engine.

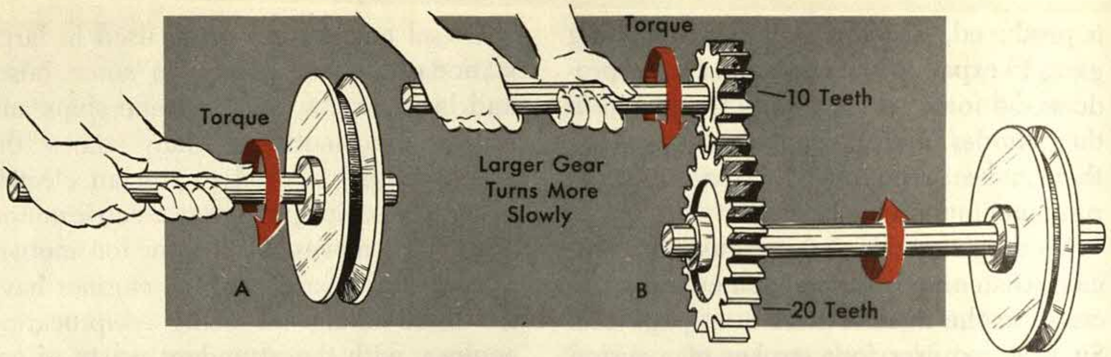
ENGINE IMPROVEMENTS

At the beginning of the twentieth century, motoring was a great adventure. In automobiles that resembled the carriages of the day, and hence were called "horseless carriages," passengers were exposed to the dust of the roads and bad weather.

The large, small-rimmed wheels sank deep into the soft roads, and the vibrations of the engines meant neither power nor dependability, but only discomfort. Hand-cranking was necessary in order to start the engine, which often failed to start.

Torque in Automobile Engines

Scientific study and experimentation have changed all that. One of the biggest improvements has been in the engine. The force to drive an automobile, usually called torque, is developed by an internal combustion engine of the four-stroke cycle type. For each power stroke, the crankshaft makes two complete revolutions. Such a single-cylinder engine vibrates strongly and delivers force unevenly. By adding cylinders and making each one deliver its power stroke at a



In A, the torque is applied directly to the wheel and delivered in a 1 to 1 ratio. In B, the torque is changed in direction and multiplied by 2 by the gears which thus act as torque converters.

different time, it is possible to make the engine run with less vibration and produce a more even flow of power. The more cylinders added, the shorter the time between the power strokes. Today passenger automobiles usually have four-, six-, or eight-cylinder engines.

Flywheel of Automobile Engines

Another method of making engines run more smoothly is to use the ***inertia*** of a heavy wheel. Scientists use the term inertia to describe the tendency of any object to continue to move once it is in motion, or to remain at rest once it has stopped moving. For example, when the brakes are applied suddenly to a swiftly moving automobile, the occupants tend to be thrown forward because of their inertia. When you spin a top, its inertia keeps it spinning after it has been started.

To reduce the vibration and help produce even power in an automobile engine, the inertia of a ***flywheel*** can be used. The flywheel is a heavy wheel attached to the crankshaft. As it turns rapidly with the crankshaft, the flywheel helps carry the pistons through their non-power strokes with very little change in speed, thus reducing the vibration.

Torque Multiplication

For an automobile to move, the engine torque must be transmitted to the driving wheels. Then, too, torque demands are often greater than the engine can deliver when it is coupled directly to the driving wheels. For example, more torque is required to start an automobile moving than to keep it moving because the automobile's inertia must be overcome. It also requires more torque to go up hill than to drive along a level road. A device for changing torque is called a ***torque converter.*** Two methods of changing torque are widely used in automobiles. One depends upon gears and the other uses an enclosed fluid—oil. Some automobiles use only gears while others use both methods.

Gear Torque Converters

A ***gear*** is a wheel with teeth around its rim. Two gear wheels with properly cut teeth can be fitted together so that, as one is turned, it will turn the other, but in the opposite direction. See diagram above.

The amount of torque multiplication depends upon the mechanical advantage of the gear system. The mechanical advantage can be found in several ways. One of the simplest is to divide the number of teeth in the driven gear by the number in the driving gear. This method neglects losses caused by friction. In the diagram, the mechanical advantage is 20 divided by 10, or 2. Thus, ignoring friction, these gears would multiply the torque by 2.

By the proper selection of gear size, torque can be increased, but always at a reduction of speed of rotation. The speed of rotation can be increased, but always with reduction of torque. By operating the manual gearshift in an automobile, the driver can select different sets of gears that multiply torque to meet the different needs for all types of driving conditions.

Fluid Drive

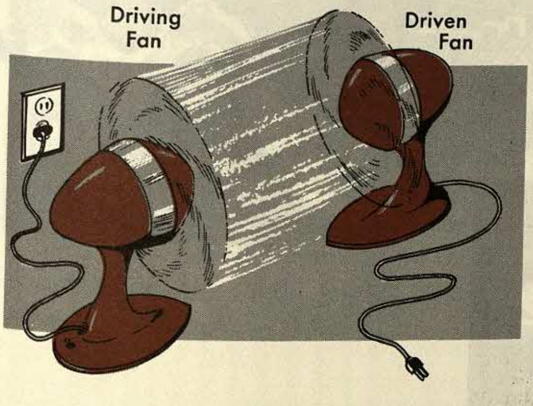
The operation of fluid drive systems depends upon the fact that torque can be transmitted by a moving fluid, such as water or oil. This fact is simply demonstrated by diagrams on this page. Some automobiles have used fluid torque transfer, known as ***fluid coupling,*** or ***fluid drive,*** for many years because it provides smooth torque transfer, which helps prevent jerky driving. Fluid coupling does not increase torque.

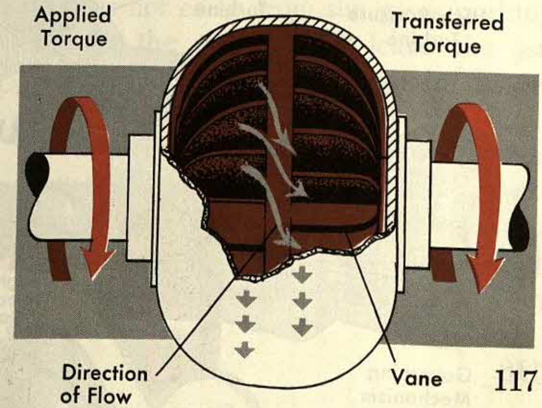
Fluid Torque Converters

By changing the design of the fluid coupling members and adding two sets of specially curved blades, it is possible to direct the oil flow so that the speed given the oil by the driving member is increased. This device is called a torque converter. The speed increase given the oil by the torque converter adds to the torque delivered to the drive member. Thus, it increases the torque delivered to the rear wheels.

The maximum torque increase with a fluid torque converter occurs when the driving member attached to the engine is rotating much faster than the driven member, which is connected to the driving wheels. This situation exists when the automobile is starting to move. For example, as the speed of the automobile increases, the speed of the driven member gradually approaches the speed of the driving member.

Air currents will turn unconnected fan as shown below. In fluid coupling, two specially designed wheels, which are enclosed in oil, transfer torque smoothly from one wheel to the other wheel.





As it does so, the torque transfer is adjusted smoothly and automatically until, at a steady car speed, under light load, the torque transfer is about 1 to 1. See the diagram on page 116. Because this change takes place so smoothly, torque converters are used by almost all automobile manufacturers.

Automatic Torque Transmission

A torque converter smoothly and automatically does much of the torque changing formerly taken care of by the manual gearshift. By using the converter with gears to provide for reversing and very high torque demands, and by including a system of automatic controls, designers have been able to eliminate the manual gearshift. Instead, a manual selector is set for the driving range required.

TURBINES

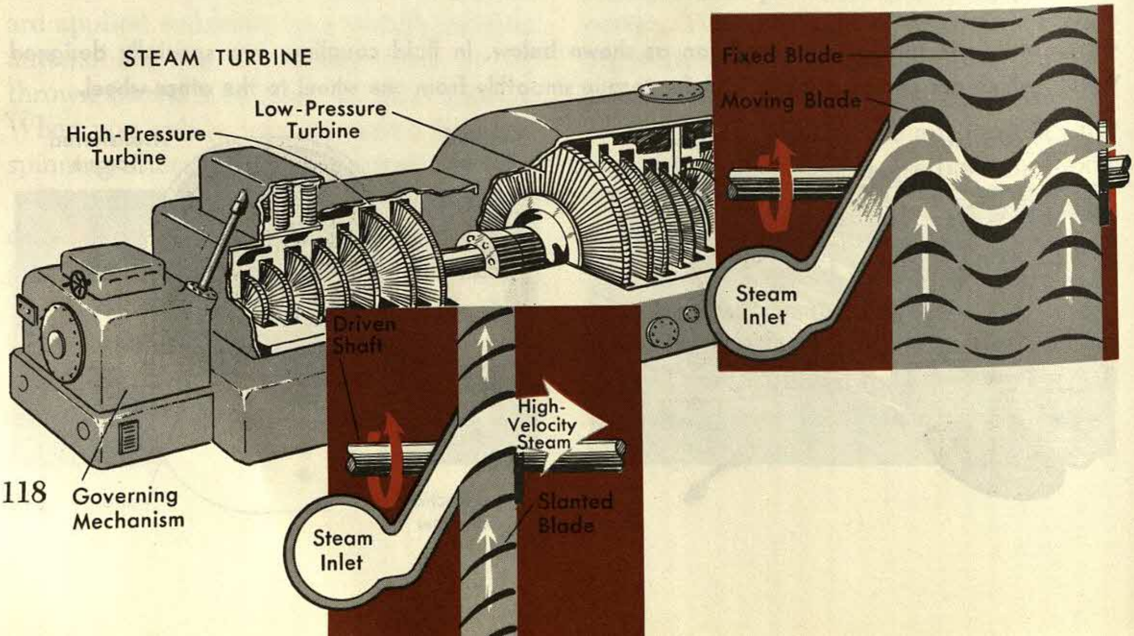
A water wheel is a type of water turbine. You can see that this engine is rotary, not reciprocating. A turbine is named for the type of fluid which drives it—water, steam, or gas.

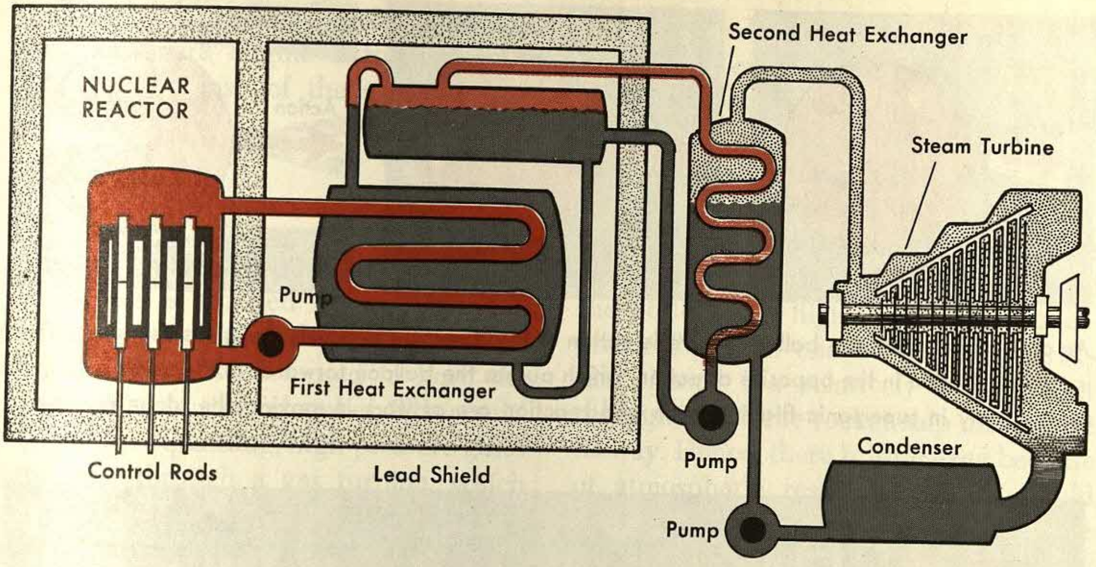
Steam Turbine

Hero, who lived in Alexandria, Egypt, in the first century B.C., made a rotary, steam-driven device. However, it was not until the twentieth century that the rotary steam engine came into its own. Steam turbines can reach 95 percent efficiency.

In 1882, Thomas Edison built a steam-powered electric supply station in New York City. It furnished electricity to fifty-nine customers and used ten pounds of coal to produce 1 ***kilowatt-hour*** of electrical power. A kilowatt-hour is a unit in which electrical energy is measured. Today's central power station can produce the same amount on less than a pound of coal. In 1959, the United States produced more than 700,000,000,000 kilowatt-hours of electricity. More than 75 percent of this was from steam power plants.

Some steam turbines are now being driven indirectly by atomic fuel. The heat from a nuclear reactor is used to form steam which, in turn, operates a steam turbine. Usually this turbine then produces electricity through an electric generator. Submarines of the "Nautilus" class,





the aircraft carrier "Enterprise," and the merchant ship "Savannah" use nuclear power in this manner. Incidentally the Savannah, christened in 1959, was named for the first steamship to cross the Atlantic. In 1819, the original "Savannah's" 90-horsepower engine used up its fuel so fast that she had to finish the trip under sail.

Gas Turbines

The airplane industry developed, as did the automotive, because of the lightweight power plant available in the form of the gasoline reciprocating engine.

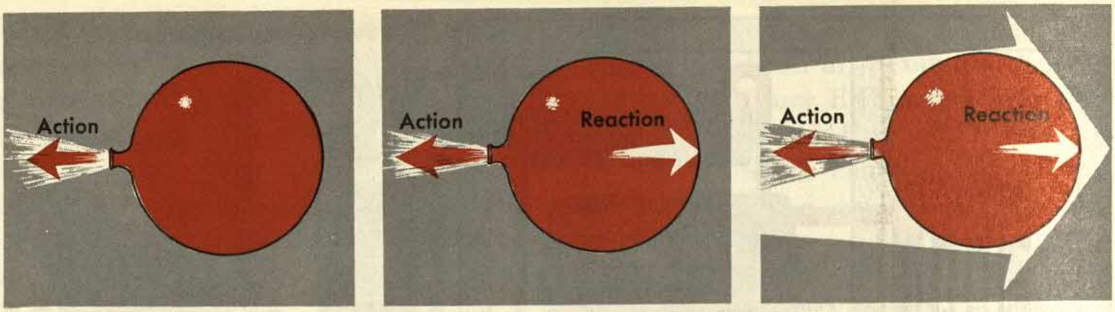
Steam engines, even steam turbines, were not successfully adapted to airplane use. When it became possible to use the exhaust gases of a regular gasoline engine to run a gas turbine connected to the drive shaft of the engine, a 20 percent increase in power resulted with no increase in fuel consumption.

With the development of alloys that could stand the high temperatures involved, it was found more efficient to do away with the reciprocating parts of the engine altogether and combine the turbine principle with the jet principle. This type of engine is particularly efficient for high-altitude flying.

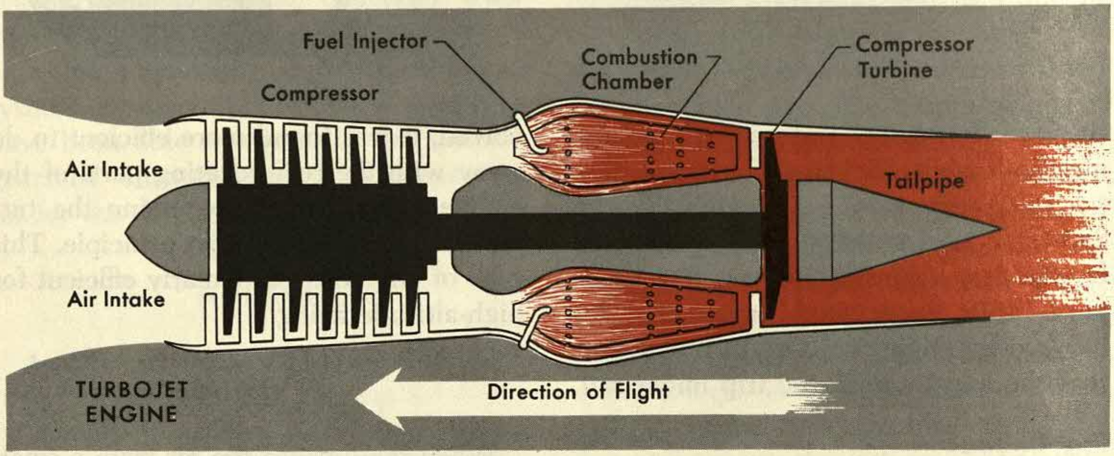
JET ENGINES

When you release the air from a small rubber balloon, the balloon darts rapidly through the air. It has become a simple jet engine. A rotating lawn sprinkler is also a jet engine. The force exerted by a jet engine is developed within the engine itself. It does not come from the gases pushing against the air as they leave the jet. Where, then, does this force in the jet come from?

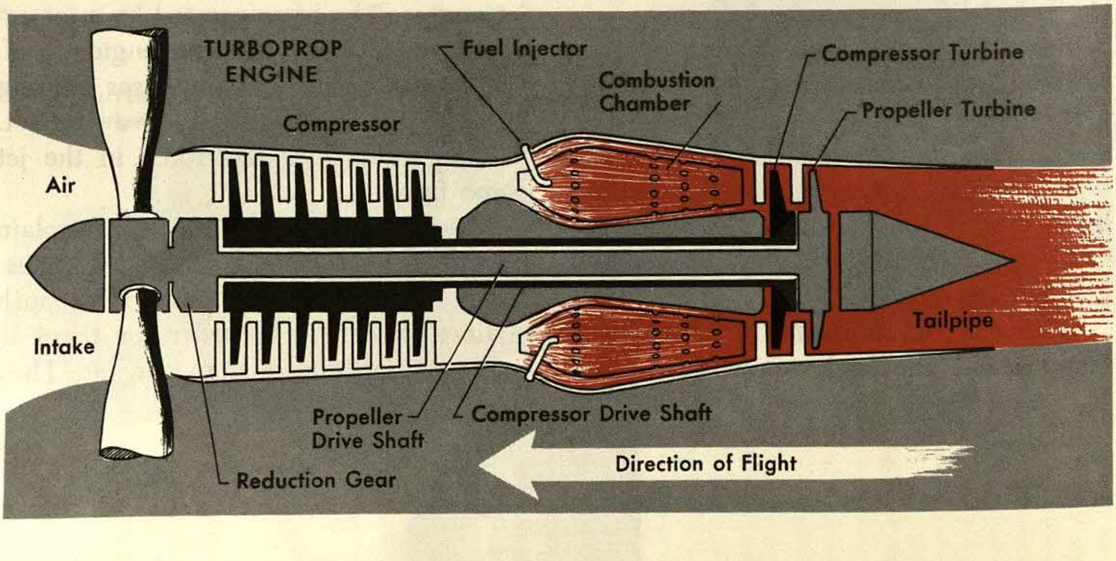
The drawing on page 120 helps explain how the force is developed in a jet engine. In such an engine, the gases must push against something in order for them to issue at high speed from the jet. They



As air escapes from the balloon, there is action in the direction in which the air is escaping. There is also a reaction in the opposite direction, which pushes the balloon forward. In the turbojet engine, used largely in supersonic flight, action and reaction are at work in moving the plane forward.



The turboprop engine is not so powerful as the turbojet. But it consumes less fuel and hence it is better for long-distance flying. Its weight is only about $1/2$ pound per horsepower generated.



push against the engine itself. They thus give the entire engine a forward push equal to the push of the gases as they leave the jets.

The Turbojet

Force from jets can also be obtained from the ***turbojet*** engine. In this type of engine, air is scooped in the front and compressed by a turbine-like compressor. This dense air is now used to burn the fuel in a combustion chamber. The resulting rapidly expanding, high-pressure gases now pass through a gas turbine, which turns the compressor. As they expand, they push on all points inside the engine, except where they escape through the tailpipe, and force the plane to move forward. This engine operates most efficiently at high altitudes because the jet of exhaust gases can escape with the least interference and thus develop the greatest ***thrust*** possible. Thrust is the force which drives an airplane forward.

When a propeller is attached to the shaft of the turbojet engine, it becomes a ***turboprop*** engine. This is not so powerful as the turbojet, but its efficiency is higher because its fuel consumption is less per pound of thrust. This makes the turboprop better adapted to long-distance, nonstop flights.

Rocket Engines

The other type of engine that depends on a jet of exhaust gases for its power is the ***rocket engine.*** Internal combustion engines, including gas turbines, need air to supply oxygen to burn the fuel. A different type of engine is, therefore, needed for flight in space, or in the rarefied atmosphere where the oxygen supply is slight. This engine must carry not only its own fuel, but the oxidizing agent as well. Solid-fuel propellants were first used as the gunpowder in sky rockets. One of the first pair of liquids used was gasoline and liquid oxygen. Today, secret formulas are being tested on launching pads around the world. Space flights differ from atmospheric flights in one outstanding particular. Space has relatively little matter through which the rocket ship must make its way. Hence, there is little ***drag*** because of atmospheric resistance which would ordinarily slow down the motion of the ship. If sufficient thrust is developed by the initial burning of the fuel to get the ship beyond the atmosphere and moving fast enough to counteract the pull of the earth's gravity, the ship will continue on at that speed without further burning of fuel until the pilot wishes to change the course of the plane.

SUMMARY

Power is the term used to describe the rate of doing work. Compound machines with high mechanical advantages are capable of doing large amounts of work fast. Man has designed many types of engines to convert energy into force and then to deliver great power.

External and internal combustion engines are used to develop power from sources of potential energy. The rotary engine is replacing the reciprocating engine in many applications because of its more efficient use of energy. The rocket engine is an effective power plant for high-speed space flight.

Activities

A. Testing Yourself

Select the ending which best completes each statement and write the letter in the proper place on your answer sheet.

1. An engine in which there is a part that moves back and forth is known as (a) an internal combustion engine (b) an external combustion engine (c) a reciprocating engine (d) a rotary engine.

2. A Diesel engine has no (a) spark plug (b) piston (c) fuel (d) cylinder.

3. The force used to drive the piston of a steam engine back and forth is obtained from (a) water put into the boiler (b) the molecules of the metal of which the engine is made (c) the kinetic energy of the molecules of steam (d) the kinetic energy of air molecules.

4. The stroke of a four-stroke cycle engine which develops the force used to drive machines is called (a) the power stroke (b) the intake stroke (c) the exhaust stroke (d) the compression stroke.

5. An engine built to operate on a force developed in the same manner as that which causes a gun to recoil when fired is known as a (a) steam engine (b) Diesel engine (c) four-stroke cycle gas engine (d) jet engine.

6. A rocket engine must (a) be very light (b) be reciprocating (c) carry its own fuel oxidizer (d) travel only where there is oxygen in the atmosphere.

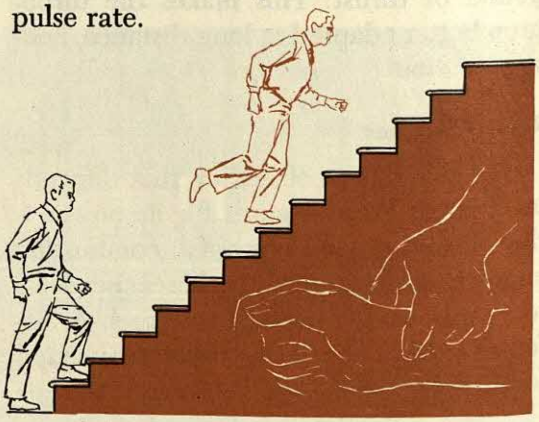
B. Making Observations

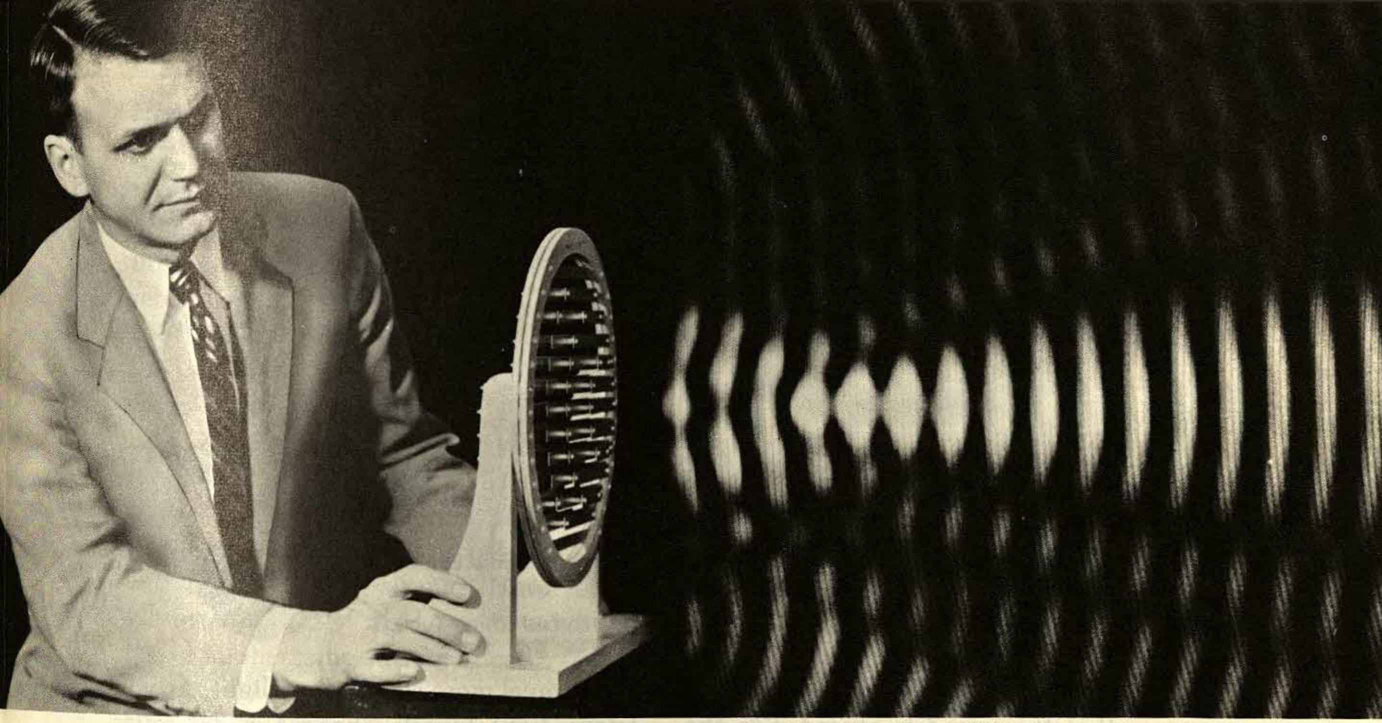
You can observe the effect upon your body of developing power at different rates by carrying out the experiment described in column 2.

Count your pulse rate by placing the tips of the fingers on the left hand against the inside of the right wrist just back of the thumb and pressing slightly. Now walk slowly up a flight of steps while someone times you accurately with a stop watch. Count your pulse rate after climbing the stairs. Find the height of one step and multiply it by the number of steps to find out how high you lifted yourself. The total height in feet multiplied by your weight in pounds will give you the amount of work you did. Find the work you did in one second by dividing the total work you did by the number of seconds it took you to do it. The work you did in one second, divided by 550, will give you the horsepower you developed as you walked up the stairs. Compare your power output to the increase in pulse rate you experienced after walking upstairs.

Repeat the experiment, but this time run up the stairs rather than walk. Again compare power output with increase in pulse rate.

Write one sentence which states the relationship between power output and your pulse rate.





Bell Telephone Laboratories

Ten-minute pattern of sound waves, above, was scanned by a tiny microphone and a neon lamp.

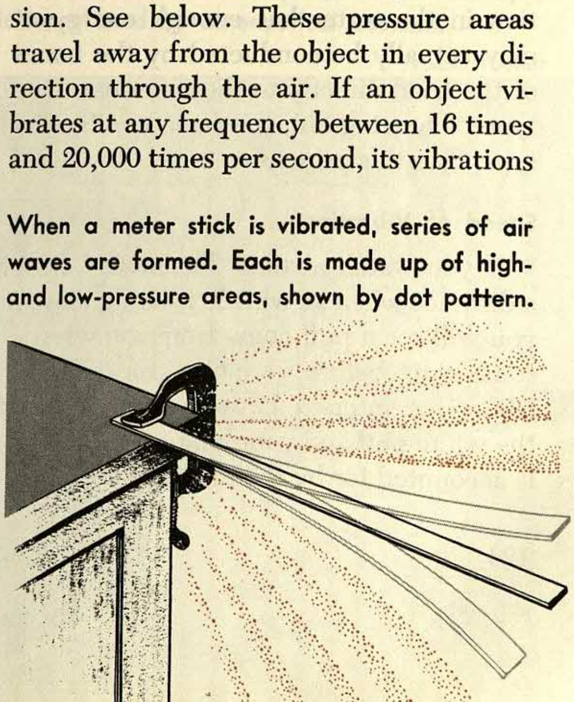
PROBLEM 6: HOW DOES MECHANICALLY VIBRATING MATTER DO WORK?

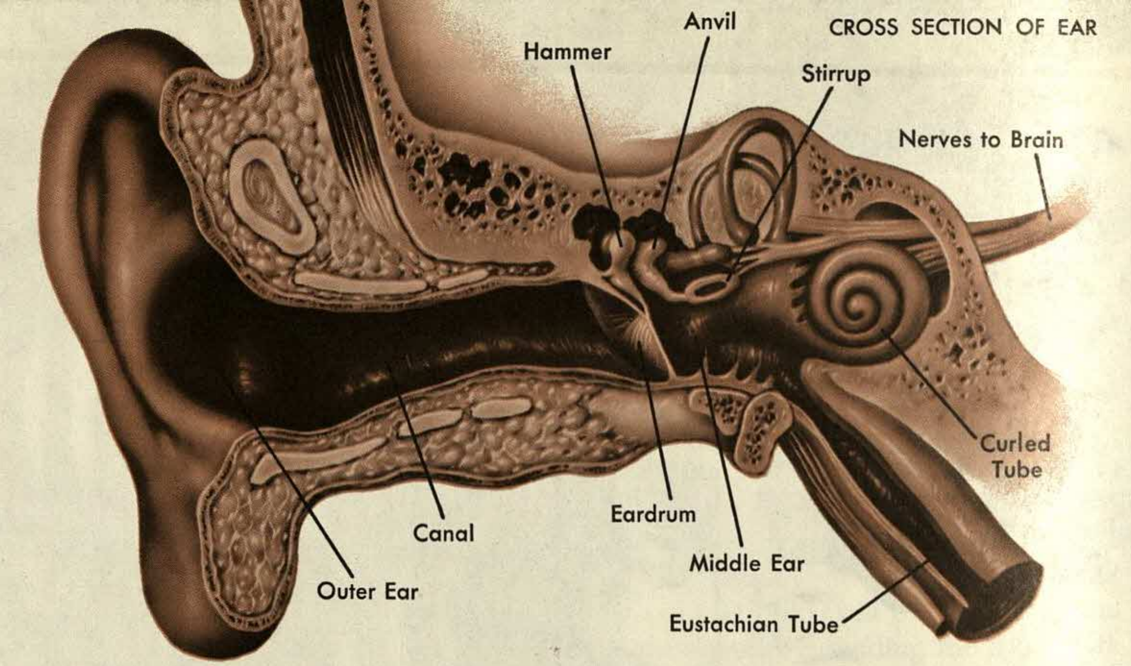
If you place your finger on the Adam's apple in your throat while you talk, you can feel something moving. If you place a finger next to a violin string while the instrument is being played, you can feel the string move back and forth very rapidly. This back-and-forth motion in throat and violin string is called ***vibration.*** The number of times any object vibrates each second is its ***frequency.***

VIBRATIONS OF MATTER

A vibrating object produces areas of alternating high and low air pressures, which follow each other in rapid succession. See below. These pressure areas travel away from the object in every direction through the air. If an object vibrates at any frequency between 16 times and 20,000 times per second, its vibrations

When a meter stick is vibrated, series of air waves are formed. Each is made up of high- and low-pressure areas, shown by dot pattern.





will affect the average human ear in such a way that the sound is sensed. See the diagram of the ear above. This sensation is usually called ***hearing.***

Air is not the only substance which can carry vibrations. If you put your ear under water in a pool or in the bathtub and scratch on a rock or on the bathtub, you will find that the vibrations are carried to the ear by the water. If the vibration in the water has enough energy, it may actually be conducted by the bones of the head directly to the inner ear. One type of hearing aid, the ***bone conduction*** type, uses this principle.

Speed of Vibrations

If you watch a steam locomotive from a distance when its whistle is being blown, you will see a puff come from the whistle some time before you hear the whistle. This time interval between your seeing the white puff and your hearing the sound is accounted for by the fact that air vibrations travel more slowly than light. As you know, light travels about 186,000 miles per second. A train whistle half a mile away would be heard in a little over two seconds.

Vibrations can also travel through many substances other than air, as you learned above. In fact, they travel more rapidly through most substances than through air, as you can see from the table below.

Approximate Speed of Vibrations In Different Substances at 20°C.

Substance	*Feet Per Second*
Air	1,120
Hydrogen	4,363
Water	4,757
Brass	11,480
Granite	12,960
Maple wood	13,480
Iron	16,820
Glass	19,680

Effect of Temperature

The speed with which air vibrations travel is also affected by temperature. Many measurements indicate that air vibrations travel at about 1,080 feet per second at sea level when the temperature is 0°C. If no other factors are considered, this speed will increase about 2 feet per second for each increase of 1°C. Thus, at 20°C., the speed would be about 1,120 feet per second. Changes in the conditions of air pressure, motion, and moisture cause this speed to vary between 1,110 and 1,200 feet per second. However, all vibrations under the same conditions travel at the same rate of speed.

Effect of Altitude

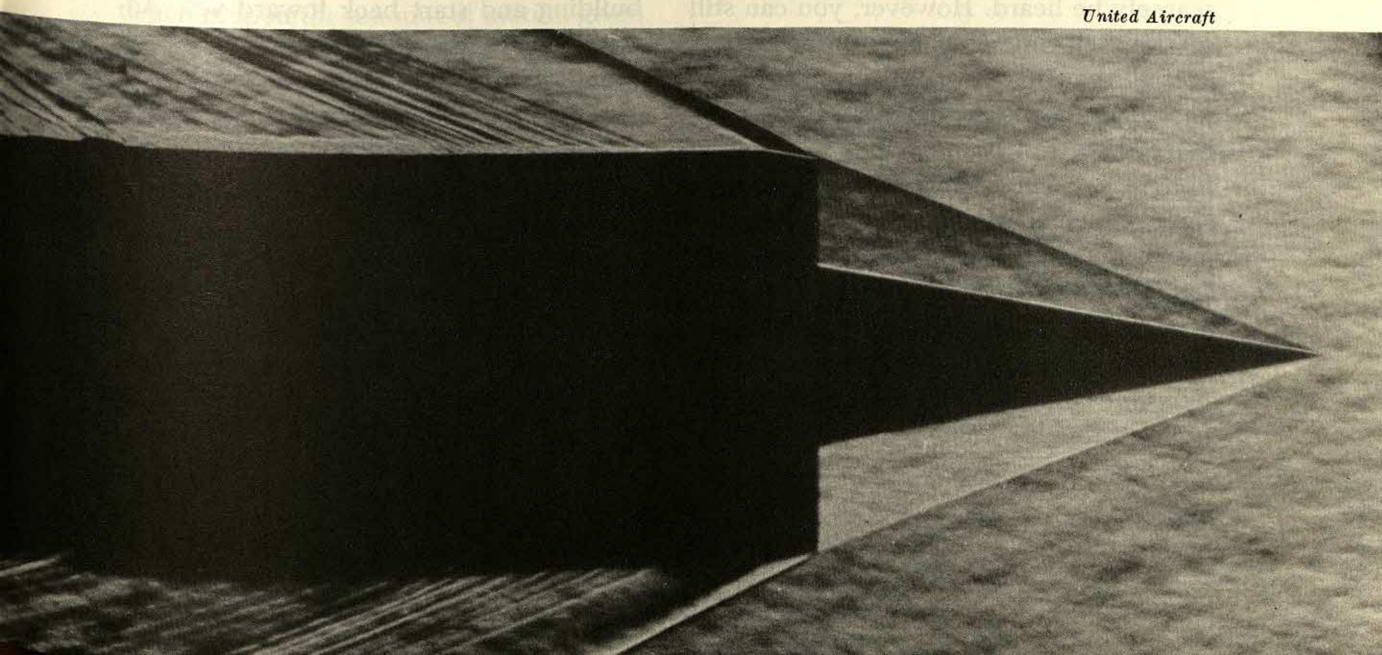
When a jet plane travels faster than the air vibrations that cause sound, it is said to "break the sound barrier." You hear a ***sonic boom,*** the result of air pressure waves created as the plane passes through this critical speed. These ***shock waves*** travel to the ground, and the boom is heard as the waves, following the plane, travel across the ground.

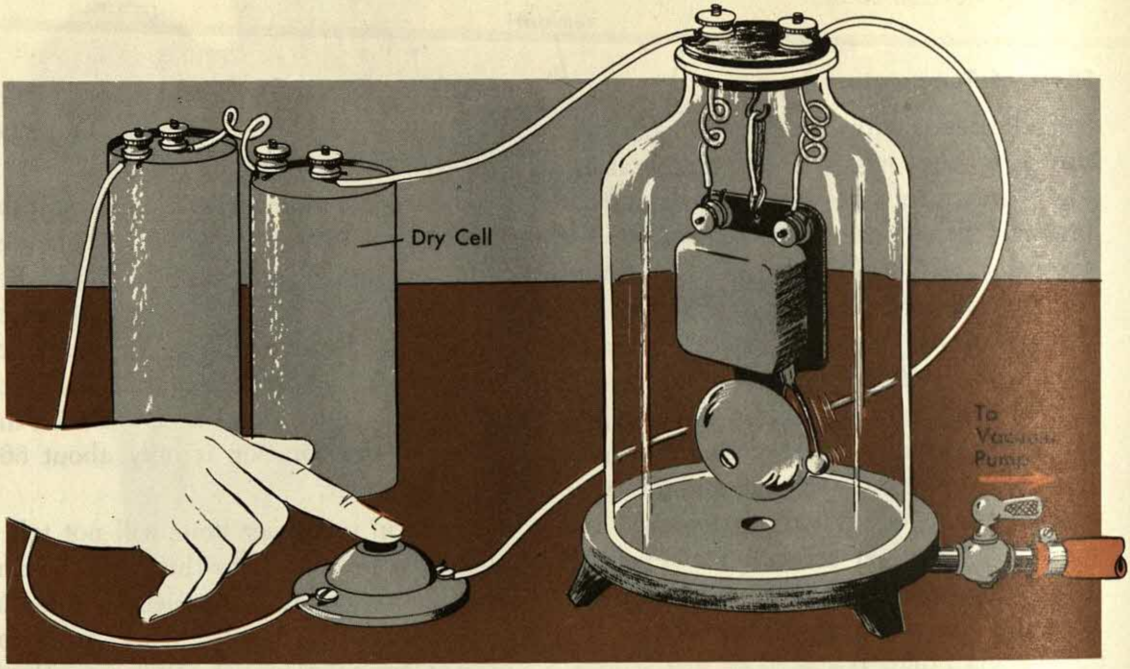
The speed of air vibration is not the same at all altitudes because it is affected by temperature and density of air. For example, at sea level, at a temperature of 15°C., the speed is about 761 miles per hour. At 35,000 feet, where the air density is less and the temperature is —54°C., the speed of air vibration is only about 660 miles per hour.

Speed in miles per hour will not tell a pilot how near he is to the sonic barrier. For this reason, airplane speed is rated in a unit called the ***Mach*** (mock) in honor of a German scientist, Professor Ernst Mach, who was one of the pioneers in the study of supersonic speed. The speed in Machs is found by dividing the speed of air vibration at the plane's altitude by the plane's speed in miles per hour. Thus you will find that the sonic barrier is always rated as Mach 1.

A speed of Mach 4 created the pattern of shock waves shown below. This pattern was made by a model of an engine inlet under test in a supersonic tunnel used for aeronautical research.

United Aircraft





Effect of a Vacuum

It can easily be proved that some form of matter is needed to carry the vibrations which are interpreted as sound.

When an electric bell is operated within a jar containing air, a sound can be heard easily. If the air is gradually removed from the jar, the sound of the bell gets weaker and weaker until finally it can scarcely be heard. However, you can still see the bell ringing as vigorously as ever.

If all the air could be removed from the jar, there would be no sound from the bell. There can be no sound from vibration in a vacuum since there is nothing through which the waves can travel to reach a person's ears. Herein lies one difference between air vibrations and radiant energy. The waves that cause sound must travel through some material, but, as you will find out later, radiant energy can travel through a vacuum.

Reflection of Vibrations

When air waves strike a smooth, hard surface, they are reflected from it with very little loss in energy. If you should stand about 110 feet from a cliff or a large brick building and shout in their direction, the vibrations would reach them in about one-tenth of a second. Some of them will be reflected from the cliff or building and start back toward you. Another one-tenth of a second will be required for the vibrations to reach you. You will hear your own voice a second time about one-fifth of a second after you have shouted. The second sound is called an ***echo.***

Echoes may be used in determining position with relation to other objects. River boatmen use echoes to help navigate narrow gorges in dense fog. If the echoes from the blast of a foghorn return to the boat from both banks of the river at the same time, the pilot knows that he is in the middle of the channel. A faster return of the echo from one bank of the river than from the other bank indicates nearness to that bank.

Experiments have shown that bats emit a high-pitched squeak and avoid objects by using the echoes.

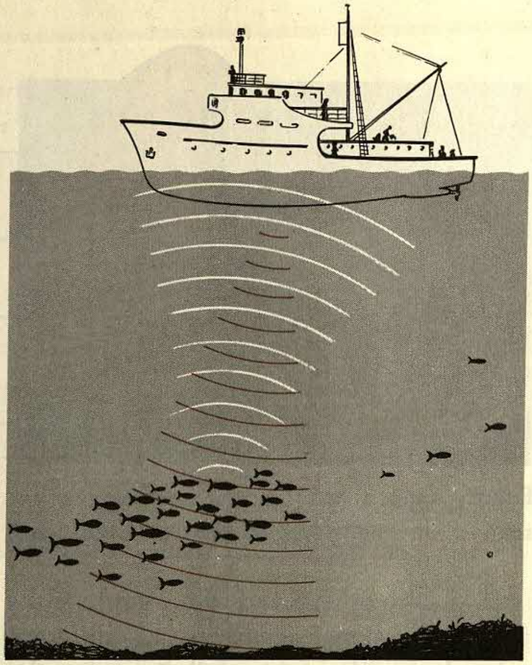
Schools of fish may be located by a *fathometer* (fa-THOM-uh-tur). This is a device which sends an underwater vibration to the bottom and receives the echo of this wave. The time it takes the echo to return to the fathometer is interpreted as the depth to the reflecting surface. Large, underwater objects can be located by this method. The fathometer has also been used in many instances to map the contours of the ocean floor.

VOLUME AND AMPLITUDE

Some sounds are so faint that they can scarcely be heard. The gentle rustle of the breeze through the trees is such a sound. Others, like the crash of thunder, are so loud as to be almost deafening. The loudness, also called the ***volume***, of any sound, depends upon the amount of motion given the air molecules by the vibrating object.

In faint sounds, the air molecules are moved only slightly, but in loud sounds, they are moved much more. In fact, the energy from an explosion may move the air molecules so much that they exert enough force to break windowpanes in buildings.

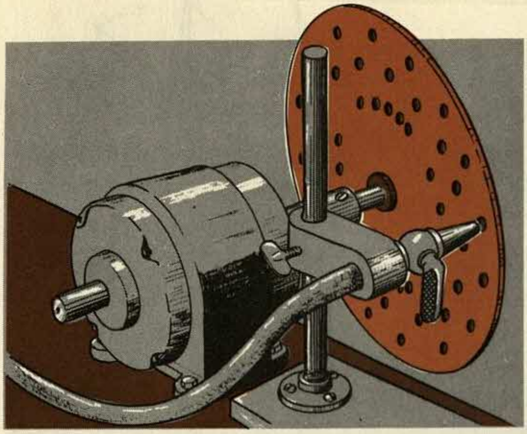
A measure of the distance the air molecules are moved is known as the ***amplitude*** of the sound waves. The loudness of sound is, therefore, dependent upon the



amplitude of the sound waves. It is often measured in units called ***decibels.*** Sounds so faint that they can just be heard are given a decibel rating of zero. By such a system, the rustle of leaves has a decibel rating of about 9, ordinary conversation of about 56, an airplane engine of about 100, and thunder of about 118.

MUSICAL TONES AND NOISE

Most of the sounds you hear are the result of a number of vibrations, each of which is occurring at a different frequency. Sounds can be considered as either ***musical tones*** or ***noises.*** Even though a sound results from vibrations occurring at different rates, the sound has a pleasing effect, and is called a musical tone if the vibrations follow each other in a regular, definite order. The sounds produced by musical instruments, singers, and birds are considered musical tones.



Equally spaced holes in disk produce musical sounds. Unequally spaced ones produce noise.

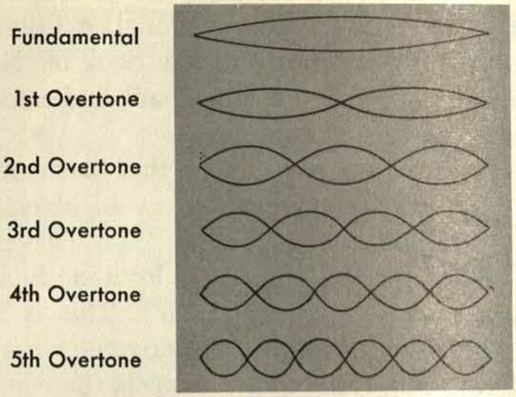
If, on the other hand, the sound results from vibrations occurring at different rates, but without any definite order, the sound is not pleasing and is called noise. Noises, such as those heard when an object is dropped, a sheet of paper crumpled, or a pane of glass broken, are produced by an irregular order of vibrations.

Pitch is the highness or lowness of a tone. Slow vibrations cause sounds of a low pitch and rapid vibrations produce those of a high pitch.

MUSICAL INSTRUMENTS

In violins, guitars, and cellos, tones are produced by vibrations of strings and by the body of the instrument.

In the clarinet, oboe, and saxophone, the tones are produced by a vibrating reed and a column of air inside the instrument. The musician plays the instrument by blowing air over a thin reed, thus causing it to vibrate. In playing a cornet or trombone, the musician's lips serve the same purpose as the reed in the saxophone.



How are the overtone frequencies related to the frequency of the fundamental in the table?

Musical tones are obtained from the xylophone by striking wooden strips which are caused to vibrate.

The quality of the tone obtained from any musical instrument is affected greatly by the size, shape, and composition of the body of the instrument.

Quality of Tones

The characteristic quality of a tone from a musical instrument enables you to tell, by the sound alone, what instrument is producing it. A single frequency determines the pitch of the tone. This frequency is called the ***fundamental.*** But few tones contain only a single frequency. They contain a number of frequencies higher than the fundamental. They are called ***overtones.*** Notice the difference in pattern of overtones shown in the table. The pattern of overtones gives a tone its characteristic quality. Without the overtone and the pattern, it would not be possible to tell one musical instrument from another when they were playing the same fundamental.

Distribution of Overtones and Percentage of Sound Contributed When Three Instruments Play the Same Tone

Instrument	*Violin Percent*	*Flute Percent*	*French Horn Percent*
Fundamental (Middle C)	60	13	2
Second overtone	8	40	10
Third overtone	20	10	50
Fourth overtone	10	20	15
Fifth overtone	2	5	5
Other overtones	0	12	18
Total	100	100	100

Tones of Different Pitch

If you examine the strings on a piano, you will find them to be of different lengths and thicknesses. The pitch of the tone produced by any string can be varied by changing the tension with which the string is stretched. This is what the piano tuner does to obtain the desired pitch when he tunes a piano.

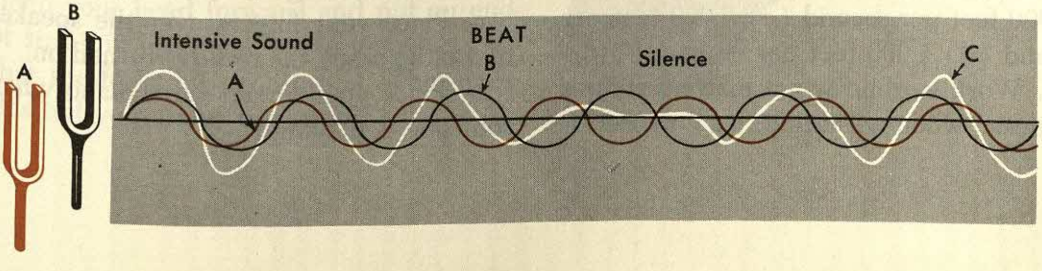
The violin is also tuned by tightening or loosening the strings. The length of the string is varied, and the different tones are produced when the violinist presses the strings at different positions with his fingers as he moves the bow across them.

The different tones are produced in some musical instruments by changing the length of a vibrating air column. In instruments such as the flute and clarinet, the length of the vibrating air column is changed by covering and uncovering the holes in the instrument. In others, such as the cornet, the length of the vibrating air column is changed by pushing down valves. The size of each wooden strip in a xylophone determines the pitch of the tone produced when it is struck.

Beats

When two tones of slightly different pitch are played, the resulting sound is first loud and then soft at regular intervals. For example, if a tone of 250 cycles per second is played with one of 251 cycles per second, the sound will become loud and then soft once each second. Thus, the tones, instead of blending together to produce a steady sound, seem to throb at a definite rate. Each throb is called a ***beat.***

Beats are produced by the alternate reinforcement and alternate interference of sound waves.



Musicians can tell when two instruments are in tune by listening for beats when they play tones of the same pitch. If none can be heard, the instruments are in tune. When musical instruments that are out of tune with each other are played together, they produce beats which make the music unpleasant to hear.

SUMMARY

Vibrating objects produce waves in the air surrounding them. Sound results from your response to these waves. The nature of the vibrations reaching your ears makes it possible for you to identify sounds as to their loudness, pitch, and quality. Vibrations can be carried by solids and liquids as well as gases, but they cannot travel through a vacuum. The speed of vibrations through air is affected by temperature, humidity, density, and altitude. Echoes of vibrations are used for such practical purposes as piloting boats and locating fish. Vibrations of musical instruments produce pleasing sounds.

Activities

A. Testing Yourself

Select the ending which best completes each statement and write the letter in the proper place on your answer sheet.

1. The number of times a substance vibrates in each second is called (a) frequency (b) amplitude (c) speed (d) loudness.

2. The fastest vibration of a substance which a person can hear is about (a) 5,000 per second (b) 10,000 per second (c) 20,000 per second (d) 30,000 per second.

3. The pitch of a musical tone depends primarily upon its (a) amplitude (b) frequency (c) overtones (d) speed.

4. The speed of sound in air at 0°C., is about (a) 20,000 feet per second (b) 10,000 feet per second (c) 5,000 feet per second (d) 1,000 feet per second.

5. Work is done when matter vibrates because, when vibrating, (a) matter is moved by a force (b) sounds are produced (c) sound acts as a type of energy (d) matter is none of these.

B. Making Reports

1. Report on the way in which ***seismologists,*** scientists who study earthquakes, are attempting to find out more about the structure of the earth by a study of vibrations.

2. Report on the way in which impulses of intense sound are being used to map the bottom of the ocean.

3. Report on the Doppler effect. List examples of where you have observed it.

C. Conducting Investigations

1. Show that anything producing sound waves is vibrating.

a. Place your fingers over the speaker of a radio when the radio is turned on.

b. Place your fingers on a piano when someone is playing it.

c. Feel your voice box when you talk.

2. Show that objects of different sizes, shapes, and materials produce different sounds when they vibrate.

a. Gently tap different objects around your home and compare the sounds you hear from each.

b. Arrange several flowerpots of different sizes as shown in the diagram. Tap them. Arrange them in order of the pitch of the sound they produce.

c. Tap water glasses which contain different amounts of water.

d. Blow across the tops of bottles which have different amounts of water in them.

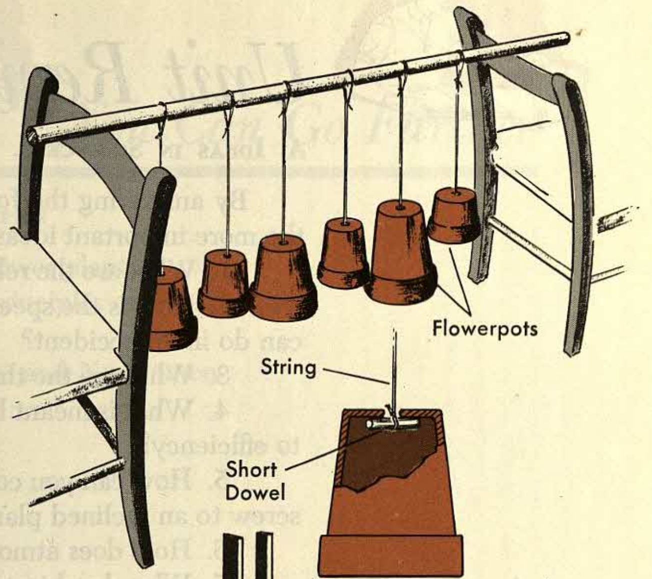
3. Have members of your class who play different musical instruments point out which part vibrates to produce the sound. How does the player change the frequency of the vibrations in order to produce different notes?

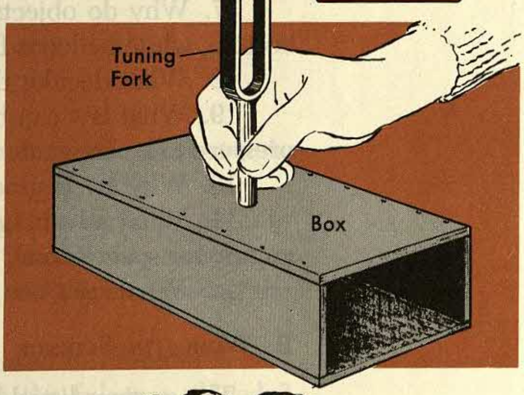
4. Tell how a box such as that shown in the diagram can be used to change the sound of a tuning fork. What does the box do to the sound? What is the effect on the sound called?

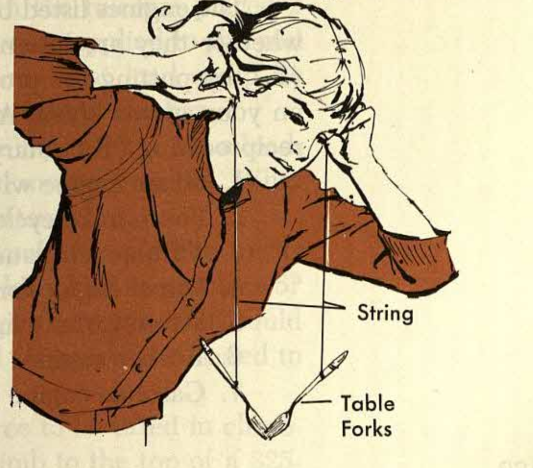
5. Use a rubber band to show how pitch increases with tension on the vibrating object.

6. Half fill a large dishpan with water. Make water waves by allowing a drop of water to fall on the surface of the water. The falling drop produces a vibrating motion. How can you show that water does not move outward, but up and down?

7. Tie forks to the ends of two eighteen-inch strings, as in the diagram at right. Bend your head forward and put an end of string in each ear. Move your head so that the forks hit each other. What does this tell you about vibrations?







Unit Review

A. Ideas in Science

By answering the following questions, you will review some of the more important ideas in this unit.

1. What are the relationships among energy, work, and power?
2. How is the speed of an automobile related to the damage it can do in an accident?
3. What are the three main reasons for using simple machines?
4. What is meant by IMA and AMA, and how are they related to efficiency?
5. How can you compare the wheel and axle to a lever and the screw to an inclined plane?
6. How does atmospheric pressure work for you?
7. Why do objects in water either float on top or sink to the bottom, while balloons float at different levels in air?
8. What decides the thickness of a dam from top to bottom?
9. What law can be stated which would lead you to expect the pressure to be the same at all the hydraulic brakes of an automobile?
10. Why are engines replacing animals as a source of power?
11. What advantages does a rocket engine have over a turbojet engine for space travel?
12. What uses can you make of the rapid vibration of matter?

B. Words in Science

The engines listed below can be classified in two ways. Indicate whether they are internal combustion (I), or external combustion (E), by putting the proper letter beside the number of the engine on your answer sheet. Also, indicate with another letter if they are reciprocating (R), rotary (O), or neither (N).

1. Steam engine with a piston that moves back and forth
2. Four-stroke-cycle automobile engine
3. Turbojet airplane engine
4. Diesel engine for a large truck
5. Steam turbine in an electric power plant
6. Rocket engine
7. Gasoline engine on a power lawn mower

You Can Go Further

A. By Preparing Reports on Special Topics

1. The gas turbine as an automobile power plant
2. A comparison of the aerodynamic principles of the autogiro and the helicopter.
3. The steam engines of Hero, Branca, and Newcomen
4. Otto's four-stroke-cycle engine
5. Power from nuclear reactors
6. Uses of ultrasonic vibrations
7. Launching of a space satellite
8. Power problems in space travel
9. Breaking the sound barrier
10. Power from volcanic steam

B. By Solving Mathematical Problems

1. How many foot-pounds of work is done when a piano weighing 750 pounds is lifted 3 feet onto a truck?

2. When a 9-foot ramp was used to load the same piano onto the truck, it was found that a force of 275 pounds was needed to roll the piano up the ramp. How much work was done in rolling the piano up the ramp?

3. What was the efficiency of the ramp used in Problem 2?

4. A 12-foot bar is used as a lever with the fulcrum placed 2 feet from one end. If a force of 200 pounds were applied to the end of the lever that is 10 feet from the fulcrum, what load could be lifted by the lever? Ignore friction and the weight of the bar.

5. It was found that with a system of pulleys used to lift a load, the force had to move 10 feet while the load moved 6 inches. What is the mechanical advantage of the pulley system?

6. Ignoring friction, how much force would be required to lift a 1000-pound load with the pulley system described in problem 5?

7. What horsepower rating would you give an engine that could be used to lift an elevator cage that weighed 15 tons when loaded to a height of 550 feet in 2 minutes?

8. Consider your own weight as the force to be lifted in climbing stairs. How long would it take you to climb to the top of a 325-

foot-high dam if you were able to work steadily at the rate of $\frac{1}{10}$ horsepower?

C. BY PLANNING ADDITIONAL ACTIVITIES

1. Devise a demonstration to prove that water pressure is greater at greater depths.

2. Set up an exhibit of common devices illustrating simple machines.

3. Demonstrate the action of air pressure on a sink plunger pushed against a smooth, flat, wet surface.

4. Devise a demonstration of lift using a model airplane wing, an electric fan, and a balance.

5. Demonstrate a Branca-type steam turbine made from a can and a toy windmill.

6. On a large diagram of a complex machine label all the simple machine elements.

7. Make a chart to show the transformation of a cloud into electric power.

8. Devise a fictional "machine" to help you get out of bed in time for school. Use as many simple machines as possible.

D. BY READING

BEELER, NELSON F. *Experiments in Sound.* New York: The Thomas Y. Crowell Company, Inc., 1961.

Book of easy experiments which demonstrate principles, behavior, and uses of sound.

BEITLER, STANLEY. *Rockets and Your Future.* New York: Harper and Brothers, 1961.

Presents fundamentals of rocketry.

BERGER, MELVIN AND CLARK, FRANK. *From Tom-Tom to Hi-Fi.* New York: Whittlesey House, 1961.

Demonstrates amazing part science plays in music. Explains sound waves, resonance, pitch, and other musical phenomena.

BROWN, CLEMENT. *Sound Recording Works Like This.* New York: Roy Publishers, 1961.

Explains principles and practices of stereophony and hi-fi.

DE CAMP, SPRAGUE. *Man and Power.* New York: Golden Press, 1961.

Presents man's conquest of his environment from the pyramids to the atomic age.

Efron, Alexander. *Mechanics.* New York: John F. Rider Company, Inc., 1958.
Good explanation of fundamental mechanics.

Efron, Alexander. *Sound.* New York: John F. Rider Company, Inc., 1957.
Complete treatment of the subject.

Ellacott, S. E. *Rockets.* New York: Criterion Books, 1961.
History of rockets from the thirteenth century to the present.

Griffin, Donald E. *Echoes of Bats and Men.* Garden City, N.Y.: Doubleday and Company (Anchor Books), 1959.
How bats, men, and sonar use radar-like echoes to navigate.

Hammond, R. *Power Stations Work Like This.* New York: Roy Publishers, 1961.
Describes operation of power stations now and in the future.

Newell, Homer E. *Guides to Rockets, Missiles, and Satellites.* New York: Whittlesey House, 1961.
Describes latest advances in American and foreign rockets.

Newell, Homer E. *Express to the Stars: Rockets in Action.* New York: Whittlesey House, 1961.
Comprehensive picture of modern rocketry.

Peieris, R. E. *The Laws of Nature.* New York: Charles Scribner's Sons, 1956.
Presents physical laws by means of simple analogies.

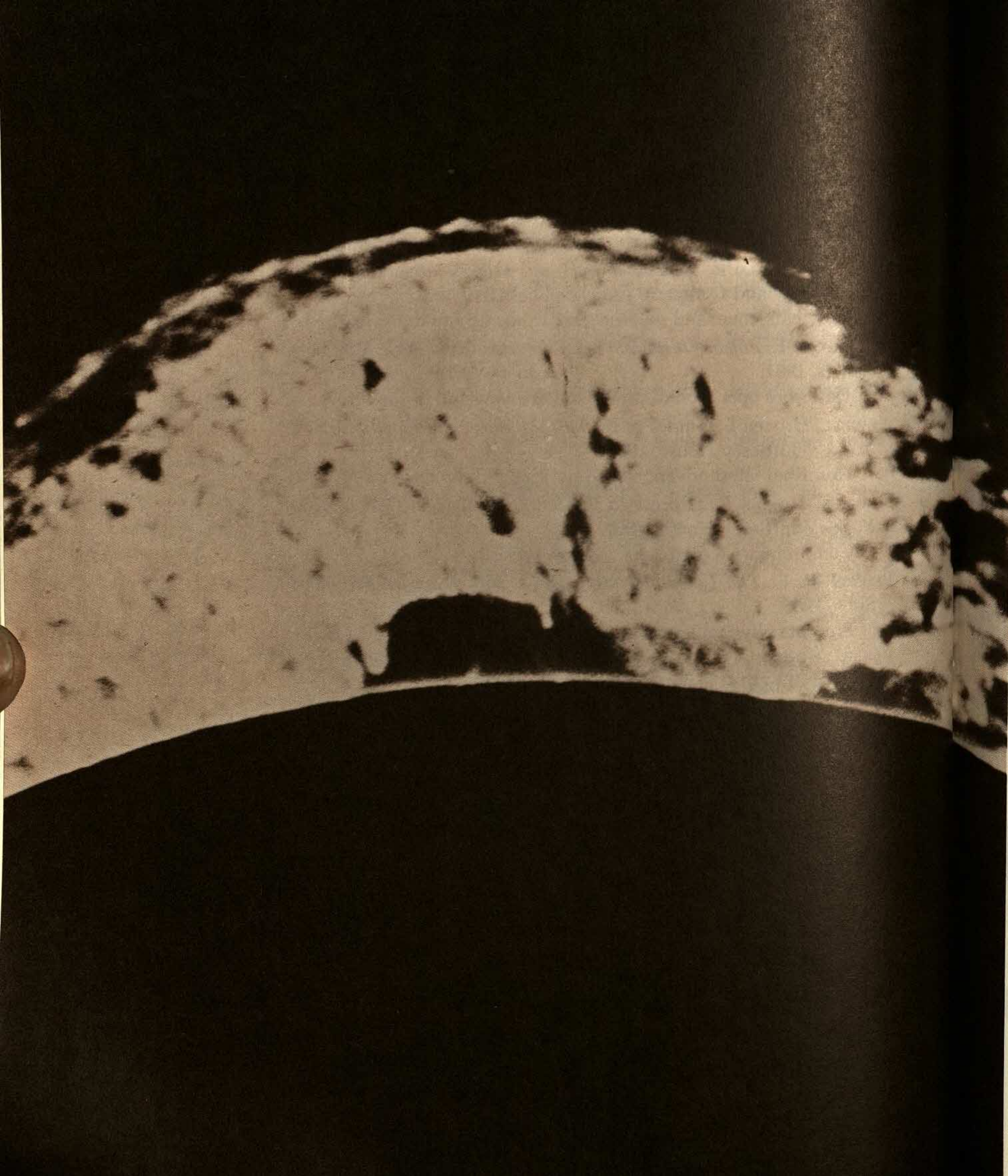
Pierce, John R. and David Edward. *Man's World of Sound.* New York: Doubleday and Company, 1958.
Brings together information from anatomy, physiology, and physics concerning the human senses of hearing and speech.

Severn, Bill. *The Story of the Human Voice.* Philadelphia: Macrae Smith Company, 1961.
Tells how man has used his voice from prehistoric times to the present.

Sutton, O. G. *The Science of Flight.* Baltimore: Pelican Books, 1955.
History of mechanical flight from arrows to giant rockets.

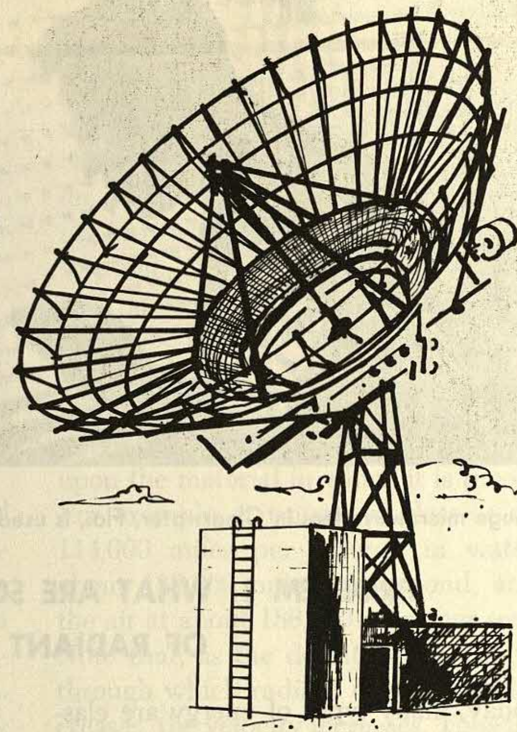
Tyndall, John. *Faraday As a Discoverer.* New York: Thomas Y. Crowell Company, 1961.
New edition of a science classic.

Wolstenholme, Kenneth. *Boy's Book of World Airlines.* New York: Roy Publishers, 1961.
Evolution of world's airplanes from simple beginnings to the super-jets of today.



Humble Oil—High Altitude Observatory, U. of Colorado

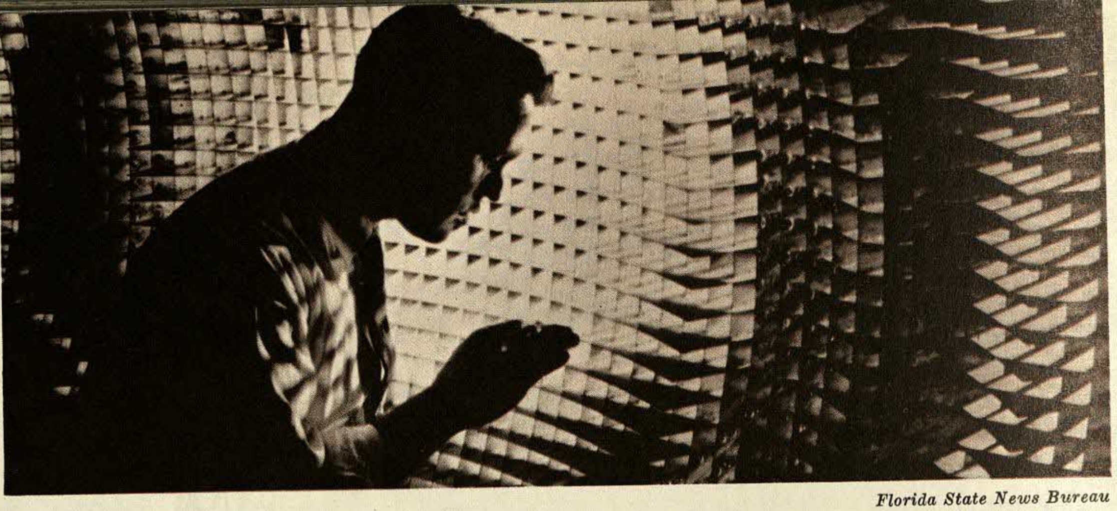
UNIT 4



Radiant Energy

In the beginning, man's discoveries about the world were very simple and were used quite directly, as in the control of fire, the making of primitive tools, and so on. Also, in early times, the discoveries were about things that could be seen or touched. As time went on, man learned to make accurate records and use them as tools for his brain. When science and man had advanced to this stage, man could stop merely wondering and begin really to make discoveries about things he could not see. One of the most important of these things was energy.

Probably one of man's greatest triumphs came when he recognized that a number of types of energy, which he had previously thought unrelated, are, in reality, closely related to each other. Once man recognized this close relationship, he was able to gain a greater understanding of the different types of energy, to state his understanding more simply, and to use them more effectively.



Florida State News Bureau

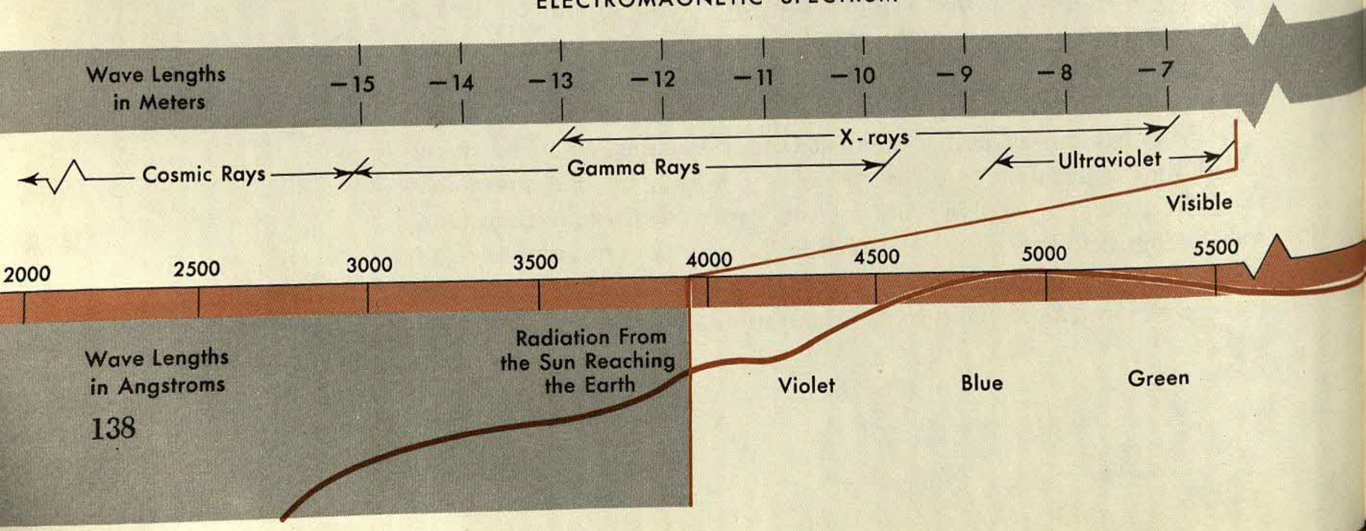
This huge microwave lens in Clearwater, Fla., is used to concentrate radiant energy from the sun.

PROBLEM 1: WHAT ARE SOME CHARACTERISTICS OF RADIANT ENERGY?

Today, many types of energy are classified under one heading—radiant energy. These include A.C. electricity, radio, infrared and light waves, as well as ultraviolet, gamma, and cosmic rays and x-rays. They are grouped together because they seem to be fundamentally of the same nature. For this reason, these types are represented on one continuous scale called the ***electromagnetic spectrum,*** shown below. It is usually referred to only as the spectrum.

The spectrum is separated into types on the basis of the effects which different parts of the spectrum produce. The names given the various types are self-explanatory. There is no precise line of separation between types. This fact is clearly demonstrated if you try to indicate just where red changes to orange in the visible range of the spectrum. The slanted lines separating one type from the other are used to indicate the fact that each type blends into the other.

ELECTROMAGNETIC SPECTRUM



SOME COMMON CHARACTERISTICS

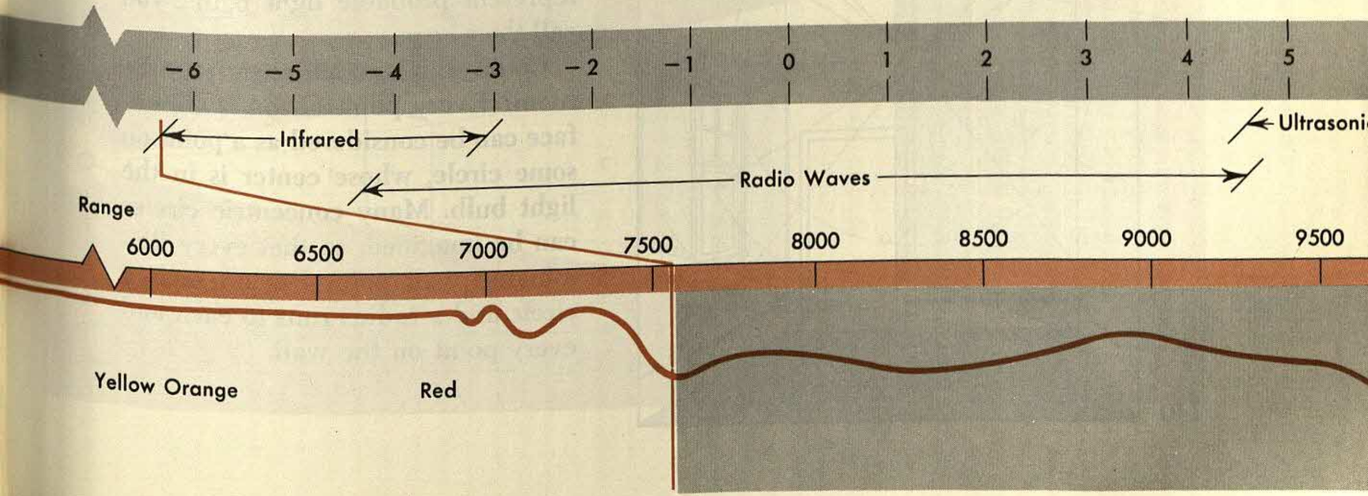
Much of man's scientific knowledge of radiant energy is very recent. This is because nearly all types are invisible. Hence scientists could not observe radiant energy directly. They had to observe what a type of radiant energy did and then try to describe it. In these scientific descriptions are found its ***characteristics.***

Velocity of Radiant Energy

It is thought that radiant energy will be least affected and will travel at its highest velocity in a perfect vacuum. These two ideas are theoretical. They have been drawn from experiences with radiant energy, but none was in a perfect vacuum.

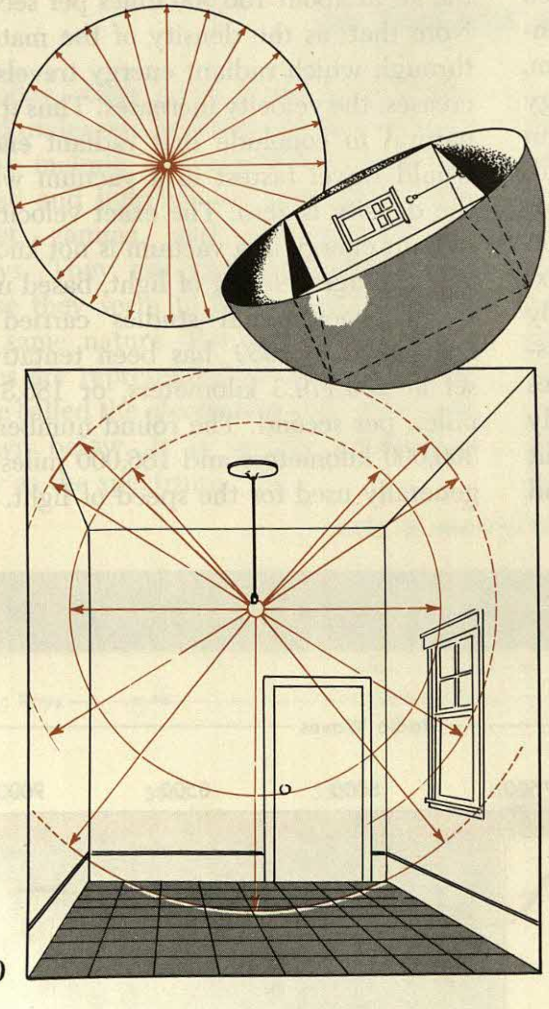
Experiments show that radiant energy acts with materials in three ways. It can be reflected, absorbed, or transmitted. The amount of reflection, absorption, or transmission depends, in each case, upon the type of energy and material. For example, a polished wood table primarily reflects and absorbs light, but it also transmits a large proportion of radio waves and x-rays which may hit it. Your body absorbs and reflects infrared rays, but transmits a large percentage of x-rays and gamma rays. All three actions occur in such amounts that they equal 100 percent of the original energy. An ideal transmitter would carry the energy without affecting it. It would exhibit no reflection or absorption. A perfect vacuum ought to be such a transmitter, inasmuch as there would be no matter to reflect or absorb the energy. Such a vacuum has not been attained on earth, but could be in space.

The velocity of radiant energy depends upon the material in which it is traveling. For example, it travels in glass at about 114,000 miles per second; in water at about 132,000 miles per second, and in the air at about 186,000 miles per second. Note that, as the density of the material through which radiant energy travels decreases, the velocity increases. Thus it was natural to conclude that radiant energy would travel fastest in a vacuum where the density is zero. The exact velocity of radiant energy in a vacuum is not known. The average velocity of light, based upon seven experimental studies carried on from 1906 to 1959, has been tentatively set at 299,779.3 kilometers, or 186,312.2 miles, per second. The round numbers of 300,000 kilometers and 186,000 miles are generally used for the speed of light.



Scientists assume the velocity of radiant energy in a vacuum to be the highest velocity attainable in the universe. In matter, however, the velocity of radiant energy is sometimes less than that of some atomic particles.

P. A. Cerenkov (chur-EN-koff) found that a beam of fast electrons would generate light when moving through a transparent medium, provided its velocity were higher than that of light in the medium. This is a new way to produce light. The light emitted is known as ***Cerenkov radiation.*** It is being used as a detector of high-velocity particles in atomic research.



Radiation of Radiant Energy

All types of radiant energy can be considered as moving from a point source along paths corresponding to spokes in a wheel. They radiate from the source in all directions. It is because of this that they receive the name radiant energy.

Imagine a single unshaded light bulb lighting a room. All wall surfaces receive light from the bulb, yet you cannot see the light moving from the lamp to the walls. You must imagine the path of light from the lamp to the walls. Check your imaginary light path with a ***radiation model*** such as the one described below.

Replace the room, in your imagination, with a sphere. Then transfer a cross section, through the center of the sphere, to paper. It will be a circle. Next imagine the light bulb to be hanging down to the center of the room, which would represent a point at the center of the circle. You can now draw radii from the center to all points on the circle. Each radius could represent the path of the light from the center (light bulb) to a point on the circle (sphere). When you let such radii represent probable light paths, you call them *rays*.

Could this model represent the room? Every point on the wall surface can be considered as a point on some circle, whose center is in the light bulb. Many concentric circles can be imagined, so that every illuminated wall point lies on such a circle and a radius runs to each and every point on the wall.

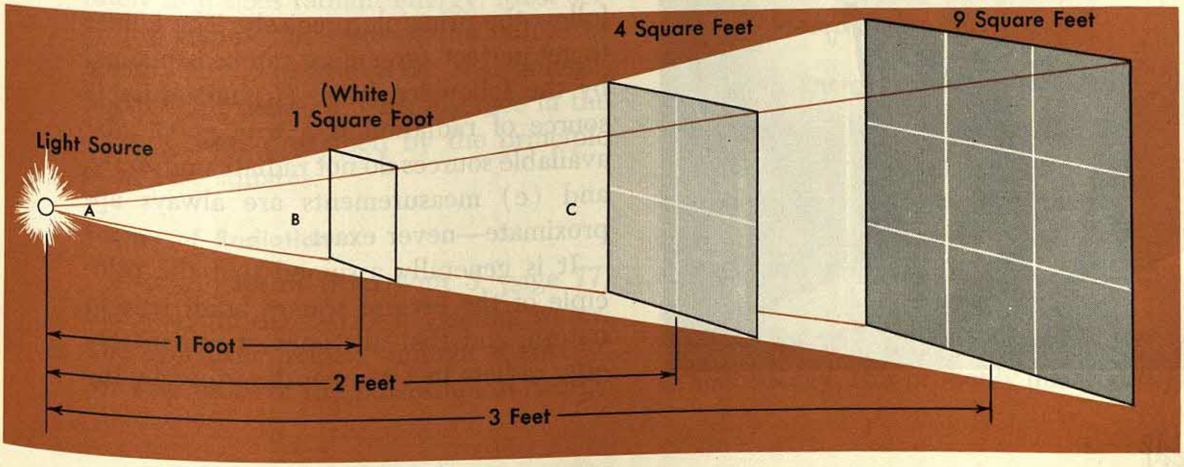
The application of the model to the lighted room seems logical. When you apply it, you say, "Light rays radiate in all directions from a point source to every point on the room walls and illuminate them directly." You still have not seen the light between the light bulb and the surface it illuminates. You assume that light travels as this model suggests because, with it, you can explain how light from a source illuminates any surface. Note especially that there is no evidence that rays of light, as you have drawn them, are in the space between the light source and the walls. Rays are only straight lines drawn on paper to give you a model. The path of the light might be curved for all you know. In fact, some optical phenomena are explained best by assuming that light travels as a wave rather than as a straight line.

Principle of the Inverse Square

If you examine an illuminated room carefully, you will see that all wall points are not illuminated to the same degree. Those farthest from the source receive less light per unit area. Measurement with a light meter will confirm your observation. Even though you measured the illumination for every wall point accurately, the measurements alone would not reveal the exact way the decrease occurs when there is a change in distance from the source. In order to understand and predict the relation of distance to illumination, you need some kind of theory stating what the relation ought to be. Such a theory has been developed. To understand it, refer again to the radiation model.

This time you need to use only a small section of the sphere—a pyramid with a square base (quadrangular pyramid), as shown in Figure A, below. The apex represents the point source of radiant energy. In Figure B, the base is twice as far from the apex as in Figure A. In Figure C, it is three times as far.

The model shows that if a bundle of rays lights a surface of 1 square foot at 1 foot from a point source, at 2 feet from the source, the rays will spread over 4 square feet. The same bundle of rays will spread over 9 square feet when the surface is 3 feet from the light source, 16 square feet when at a 4-foot distance, and 25 square feet when it is 5 feet from the light source. If you study these figures,



you will recognize that the increase in surface area is exactly proportional to the square of the ratio of the distance of the surface from the light source. That is, when the distance is doubled, the area increases four times. When the distance ratio is 3, the area increase is 9. When the ratio is 4, the area increase is 16.

Now in this model, with only one source of light, there would have to be the same number of rays covering each unit of area. If the sphere expands, the rays on each unit of the area illuminated decrease at the same rate at which the area increased. When the distance is doubled, the area illuminated increases 4 times. The rays per unit area, therefore, decrease to ¼. When the distance ratio is 3, the area increase is 9. Hence the rays per unit area decrease to ⅑, and so on. Thus, for this model you can make this exact mathematical statement: *The change in illumination (rays per unit area) of a surface by a point source is inversely proportional (decreases as distance increases) to the square of the ratio of the distance of the surface from a point source.*

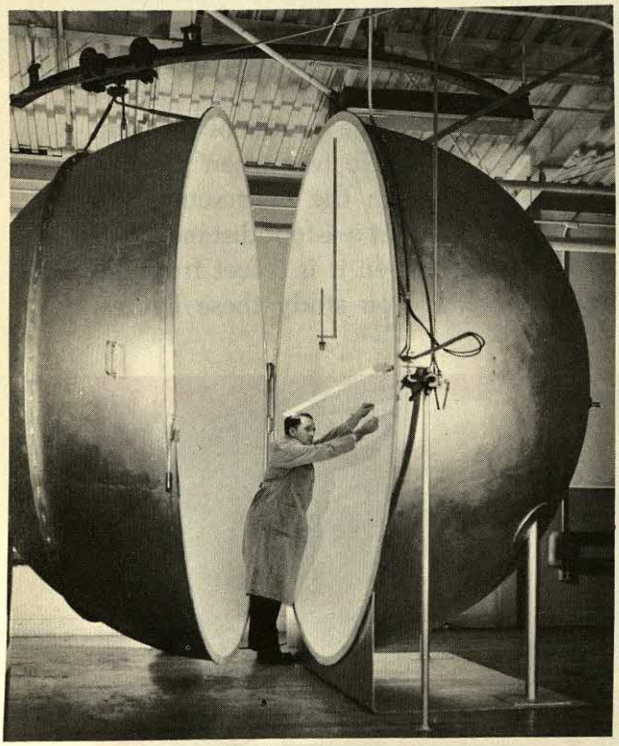
Now cut your sphere in half and move one section farther from the light source than the other section. If you think of the first surface as a ***unit surface*** at a ***unit distance***, and if you consider its measurement as equalling 1, the statement can be shortened to: *The illumination of a surface varies inversely as the square of the distance from a point source.* This statement is known as the principle of the inverse square of illumination.

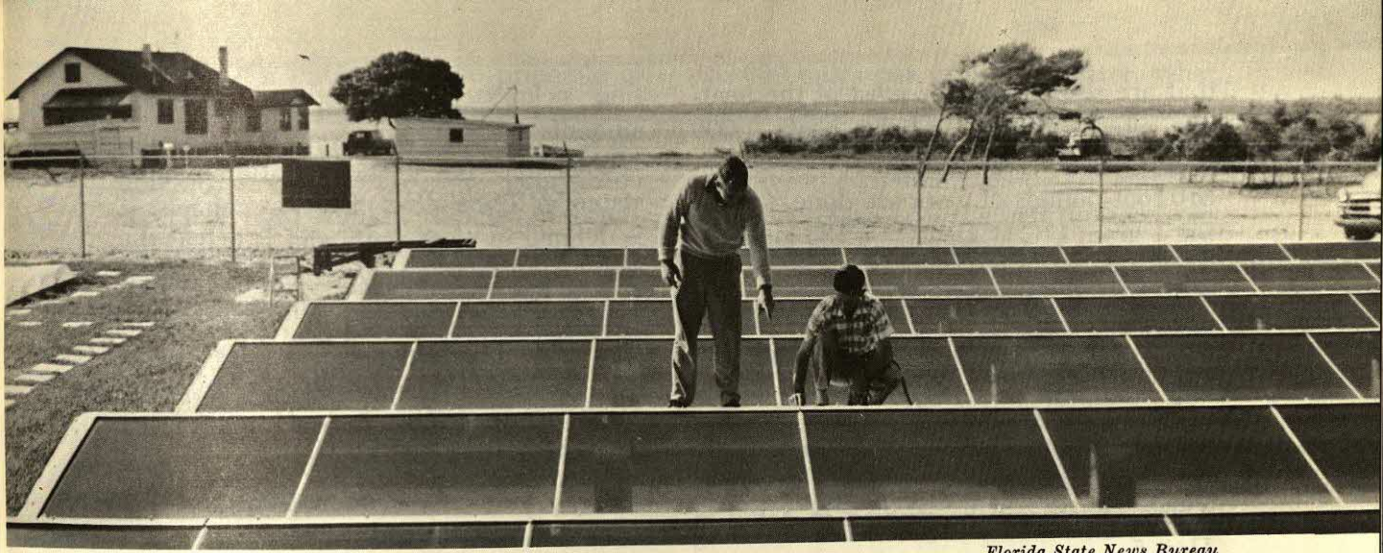
Does illumination of the room surfaces follow the inverse square principle? Scientific measurements do not agree precisely with the exact mathematical statement. However, most scientists use this principle as though it were a law because they suspect that, if their measurements were 100 percent accurate, the results would follow the principle precisely. The failure to get perfect agreement can be explained by the following facts: (a) no available source of radiation is a true point, (b) available sources do not radiate uniformly, and (c) measurements are always approximate—never exact.

It is generally assumed that the principle of the inverse square holds true in nature, and that all types of radiant energy radiate in a manner described by the

Spherical photometer makes it possible to measure intensity of illumination accurately.

General Electric Corp.




Florida State News Bureau

In these solar stills, radiant energy from the sun is used to convert the sea water into fresh water.

principle. This is another reason why all types are classified under the one heading —radiant energy.

In Unit 2, you made a model for a gravitational field by using lines to represent the paths of falling objects. These paths turned out to be radii extending from a point—the center of gravity—outward. They are similar to the radii used to represent light rays. Therefore, the principle of the inverse square ought to describe the action of gravity. Experience shows that it describes gravity as accurately as it does radiant energy. Most scientists assume, in spite of the failure of measurements to fit exactly, that gravitational fields decrease with distance in the same manner described by the principle of inverse squares.

Energy of Radiation

You will recall from Unit 3, page 77, that sunlight does work in heating water. The conclusion is that sunlight is energy. Another proof of the possession of energy by something is its ability to exert a force. Does sunlight push on objects it strikes? Scientists agree that it does. They estimate the total force of sunlight on the earth's illuminated surface to be about 100,000 tons. Also, the force of sunlight on a comet's tail is assumed to cause it always to point away from the sun. Some scientists are considering the use of "light winds" for "sailing" in interplanetary space travel. Thus, both its heating effect and its ability to exert a force on objects lead scientists to believe that sunlight is energy. All other types of radiation are also considered to be energy.

Recovering Energy of Radiation

Researchers have found evidence that the energy of radiations accounts for the various effects observed when they fall on objects. You are aware of their energy only when it is transformed to some other form. For example, you are aware of the energy of sunlight when it is transformed to heat energy. It is probably infrared rays that are responsible for most of the heating effect. When sunlight heats 1,000 grams of H_2O (about a quart) 10°C, 30,870 foot-pounds of work are done. (Heating 1 gram $1°C = 1$ cal. $= 4.186$ joules $=$ 3.087 foot-pounds.) This is the work that would be required to raise a liter of water about 3 miles. The energy required to warm ocean waters must be very great.

Radiant energy, in the form of alternating-current electricity, is known by the heat and magnetism it produces. These effects will be studied in detail in Unit 5.

The energy of ultraviolet rays, x-rays, and gamma rays accounts for their chemical action on film, as well as for their effects on the body. Certain ultraviolet rays penetrate the skin, destroy cells, and cause sunburn. X-rays and gamma rays can also destroy cells and produce radiation sickness if received in too great amounts.

One unit for measuring radiation is stated in terms of its effect on animals. It is defined in work units and is called the ***rad***, or radiation dosage. It is the amount of radiation which causes 100 ergs of work to be done on 1 gram of soft tissue.

The recognition of all types of radiation as energy is another basis for classifying them as radiant energy.

SUMMARY

All types of radiant energy can be thought of as moving outward from a point source in straight lines or rays. They move in a way described by the principle of the inverse square. They can also be considered to be energy, since all seem to be capable of doing work.

Activities

A. Testing Yourself

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. A continuous scale representing all types of radiant energy is called (a) the electromagnetic spectrum (b) a ray (c) a characteristic map (d) a gray scale.

2. The statement that radiant energy reaches its highest velocity in a vacuum (a) has been proved experimentally (b) is a fact (c) is a deduction (d) has not been proved experimentally.

3. Scientists believe radiant energy travels with least loss in a perfect vacuum because (a) the losses in a vacuum have been measured (b) it seems logical (c) glass is a better transmitter of sunlight than water (d) sunlight comes to earth without loss.

4. Scientists often assume that radiant energy travels as rays because (a) they have seen such rays (b) rays are known to exist (c) no other mode of travel is possible (d) it helps them to explain some of their observations.

5. Most scientists use the principle of the inverse square as though it described radiation accurately because (a) available light sources are true points (b) available light sources radiate uniformly (c) measurements are never accurate (d) they prefer to follow rules.

B. Working Problems

1. If the velocity of light were thought to be 299,900 kilometers per second, how many miles per second would this be? (1 mile = 1,609 meters)

2. If the velocity of light is measured as 132,000 miles per second in water, what is its velocity in kilometers per second?

3. If the illumination of one surface by a point source is 400 times that of another, how much farther is the first surface from the source than the other?

4. A swimming pool 20 feet wide and 40 feet long is filled with water to a depth of 6 feet. How many foot-pounds of work are done in heating the water 4°C?

5. Assuming a lethal (killing) dose of gamma rays to be 600 rad, how many ergs of work would have to be done on 100 grams of soft tissue to achieve it?

PROBLEM 2: HOW DOES RADIANT ENERGY TRAVEL FROM PLACE TO PLACE?

In Problem 1, you learned that you could think of the path of radiant energy from one point to another as a straight line called a ray. But just how does the energy get from point to point? In what way does it travel in a vacuum at such a tremendous velocity? These questions have puzzled scientists for decades and they are still far from being answered. However, it will be instructive to study some of the ideas physicists have developed while studying these questions.

WAVES OF RADIANT ENERGY

Since early times, mankind has recognized that wave motion can carry energy from place to place. In the fifteenth century, Leonardo da Vinci (lay-uh-NAHR-doh du VEEN-chee) wrote of waves on water: "The impetus is much quicker than the water, for it often happens that the wave flees the place of its creation, while the water does not; like the waves made in a field of grain by the wind, where we see waves running across the field while the grain remains in place."

The Medium

Two facts about waves stand out. First, there must be something called a ***medium,*** which transmits the waves. The medium, however, does not move along with the wave. Second, the velocity of a particular wave depends upon the medium transmitting it. From the first fact, it was clear that if light were to move as a wave, there must be some medium in space to transmit it. None could be found.

For many years, all explanations of light, and, therefore, of radiant energy, were based upon the idea that energy moved from place to place by waves in a fluid, ***ether.*** Scientists have discarded the idea that light travels in such a fluid. Yet tests are still conducted to see if such a fluid can be detected.

Tests for Medium

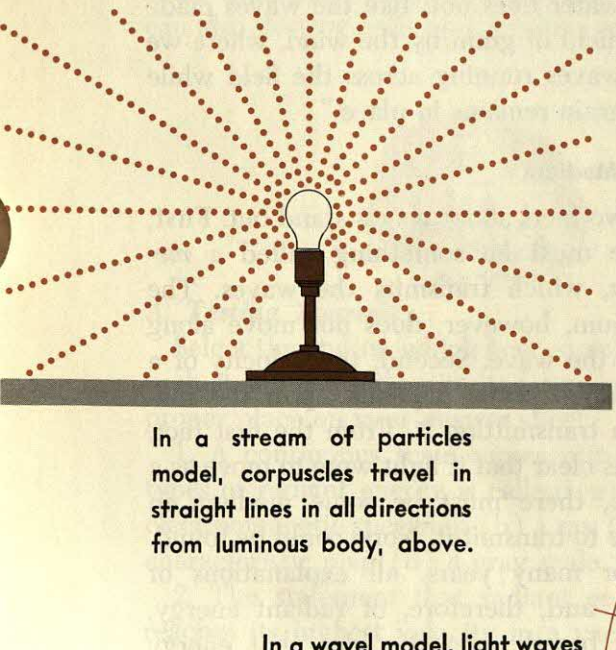
One of the latest tests was done by Dr. Charles H. Townes and John P. Cedarholm at Columbia University in New York City in 1959. Their experiment showed that if there is a fluid, ether, in space, earth's motion through it would affect the velocity of light less than 0.02 miles per second. It is, therefore, difficult to continue to believe in ether in space. Can you explain why? A few people still speak of radio and television waves as being "broadcast through the ether." But waves in ether should not be regarded like waves in water. Water waves are not a good model to use with radiant energy. Better ones have been devised.

WAVE MODEL FOR RADIANT ENERGY

Since radiant energy cannot be seen, models have to be used. Two models have been developed. One is a ***wave model.*** The other is a ***stream of particles model.*** For the last three centuries, scientists have been trying to decide which model is the more accurate. Since 1909 the problem has changed from, "which model is the more accurate" to "how can both models be related to radiant energy?"

Wave Characteristics

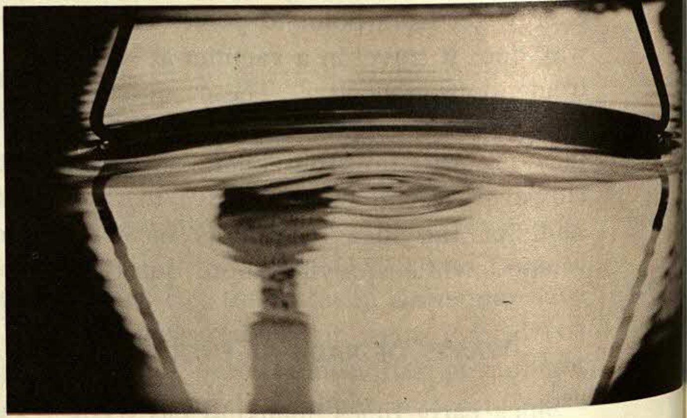
There are two steps in developing and applying the wave model. First, you need

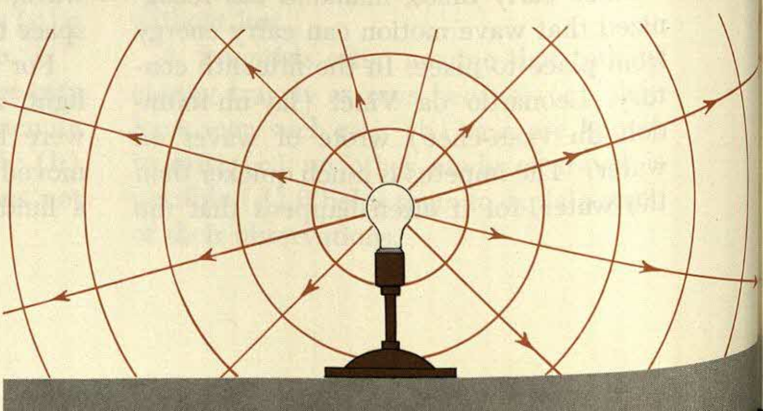


In a stream of particles model, corpuscles travel in straight lines in all directions from luminous body, above.

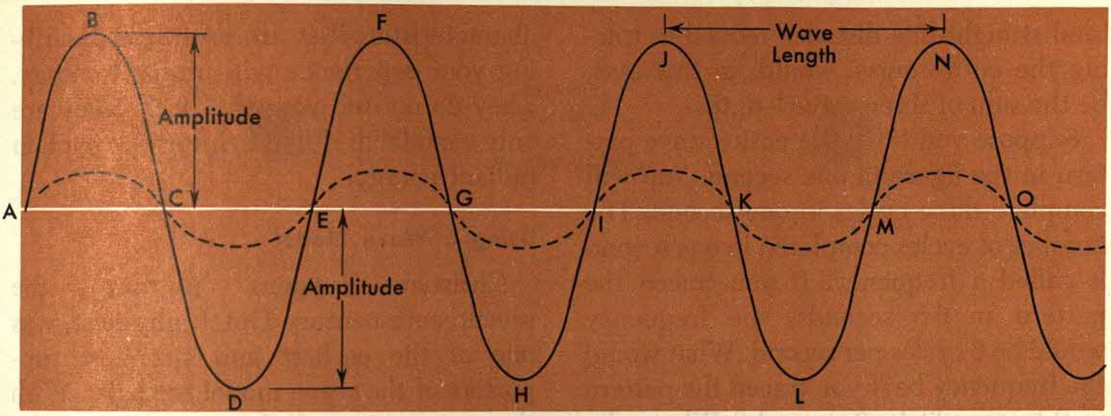
As a visible analogy to light, waves of very short length were generated in laboratory.

Vitro Laboratories





In a wavel model, light waves travel in much the same way as do water waves, above.



to identify the characteristics of waves, that is, ideas about waves that are not limited to one type but can be applied universally to all waves. Next, you need to study radiant energy to see if it possesses any characteristics such as those of known waves. You can call them the ***wave characteristics*** of radiant energy.

Suppose that the diagram on this page represents a cross-section view of a water surface. The horizontal line is the surface when the water is still. The solid curved line is the surface at some instant of time after an energy wave has started moving through the water. The drawing can be considered as a model of an energy wave moving through water. Now study the diagram to see what you can learn about energy-wave characteristics from it.

Begin to study the diagram by observing the position of your hand as you trace the solid curve from left to right. In moving from A to E, your finger starts at the horizontal line, goes once above and once below it, and then stops at it. In tracing the curve from E to I, your finger must follow a similar set of positions. If, in imagination, you should trace this curve far out into space, you would repeat this set of positions over and over. Such set of positions, or events, which are continually repeated; is called a ***cycle.*** Thus there is a cycle of seasons, of day and night, and of moon phases. On the curve, each set of positions in moving from A to E, B to F, D to H and E to I represents one cycle. What other set of positions could be a cycle?

If you traced the dotted, rather than the solid, curve, there would be only one difference in the set of positions. The maximum vertical distance above and below the horizontal line would be less. This vertical distance is called amplitude.

As you trace a cycle, say,from A to E, you do not think of your hand as moving horizontally. Yet the cycle ends at E, which is to the right of A. The horizontal distance between A and E, or J and N, is a ***wave length.*** It represents the straight-line distance that your hand traveled as you traced one cycle. Wave length is usually represented by the Greek letter lambda, written λ. It is evidence that the total straight-line distance moved in tracing the entire curve would, in this case, be the sum of three wave lengths.

Suppose you trace the entire wave pattern in the figure in one second. You will complete three cycles in one second. The number of cycles completed in one second is called a frequency. If you traced the pattern in 0.5 seconds, the frequency would be 6 cycles per second. What would the frequency be if you traced the pattern in 0.1 second? In 3 seconds? What relationship is there between the frequency, the wave-length, and the straight-line distance covered in the diagram? It is this: The straight-line distance is equal to the wave length multiplied by the frequency, or, expressed as a formula,

$$d(\text{distance}) = \lambda\ (\text{wave length}) \times f(\text{frequency})$$

The frequency of most radiant energy waves is so high that, for convenience, it is often stated in kilocycles (1,000 cycles) or megacycles (1,000,000 cycles) per second. Most radios can receive waves between 500 to 1,500 kilocycles, as indicated on the dial. Cycles per second are abbreviated as cps.

So far, you have learned that the movement of a hand in tracing the diagram can be described by cycle, amplitude, frequency, and wave length (straight-line distance). These words describe the characteristics of the motion of something traveling along the wave pattern in the diagram. Can these characteristics be used to describe radiant energy? Scientists believe they can, provided you remember that the characteristics themselves are not radiant energy. They are simply wave characteristics that are useful in describing your experience with radiant energy. They do not tell you what it is. They are only a model useful in helping you explain radiant energy.

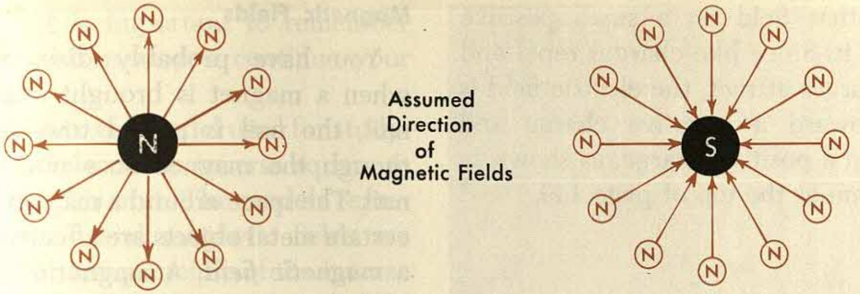
Using a Wave Model

Christian Huygens (HI-gunz), the seventeenth-century Dutch physicist, was one of the earliest and strongest supporters of the wave model for light. With the assumption of the existence of the fluid ether, his analysis of light transmission by waves was so successful that it became an accepted fact in the scientific world. A student of physics who explained light transmission in any other way would probably have failed his course as late as 1850. See diagram on page 146.

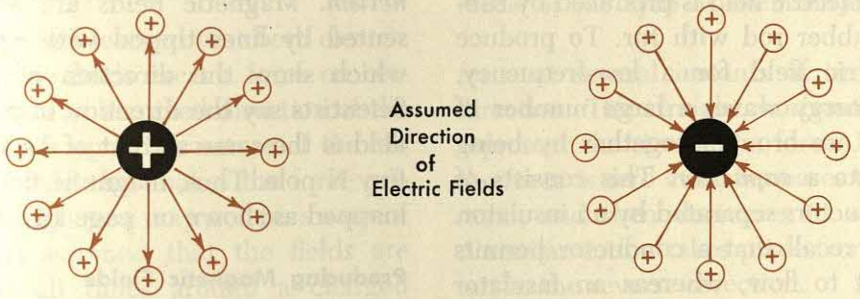
A wave model is still used, but it is considerably changed from the one popular in the nineteenth century. The newer model calls for electric and magnetic fields moving through space and presenting certain wave characteristics.

All of the space around an electrically charged object such as that studied in Unit 2, page 32, is called an ***electric field.*** You were made aware of an electric field by its effect on pith balls or other low-mass objects placed in it. An electric field seems to behave much like a gravitational field with one exception—it exerts an electric force on objects rather than a gravitational force.

Electric fields, like gravitational fields, can be represented by lines tipped with arrowheads. The lines represent the electric force, while the arrowheads show its direction. The direction of the electric field is assumed to be the same as the



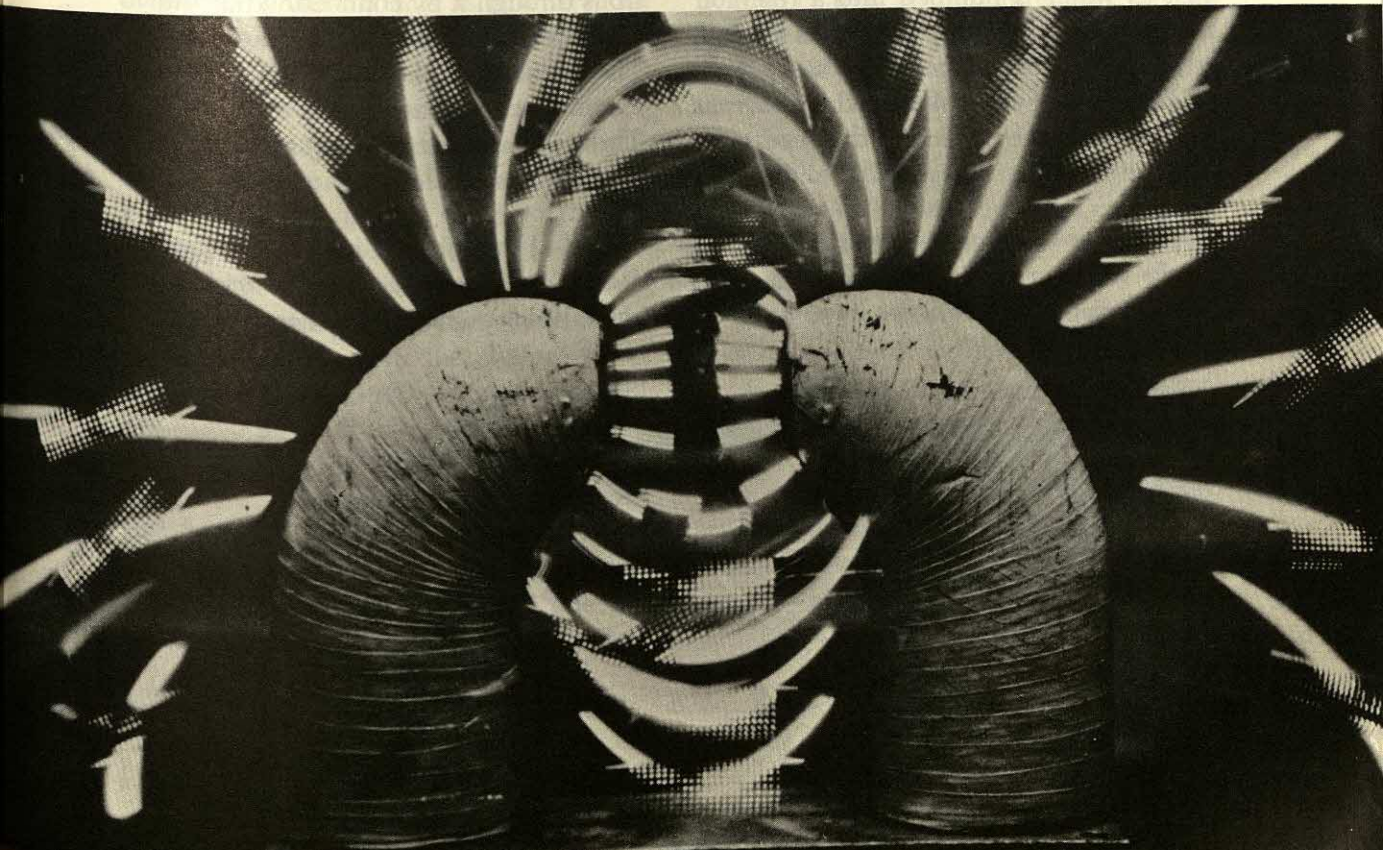
Assumed Direction of Magnetic Fields



Assumed Direction of Electric Fields

Magnetic field around powerful electromagnet was made visible by its action on gas in tube, below.

Science Service



force of that field on a small positive charge in it. Since like charges repel and unlike charges attract, the electric field is always toward a negative charge and away from a positive charge, as shown in the diagram at the top of page 149.

Capacitor

To produce an electric field, a large number of electrons must be brought together at one place. This is what happens when an electric field is produced by rubbing a rubber rod with fur. To produce the electric field for a low-frequency, radiant-energy wave, a large number of electrons are brought together by being forced into a ***capacitor.*** This consists of two conductors separated by an insulator. You will recall that a conductor permits a current to flow, whereas an insulator does not. A capacitor seems to store electrons as a storage reservoir stores water. Just as water is pumped into a reservoir for storage and released for use as needed, so electrons can be forced into a capacitor to be released later. While the electrons are stored in the capacitor, they create an electric field.

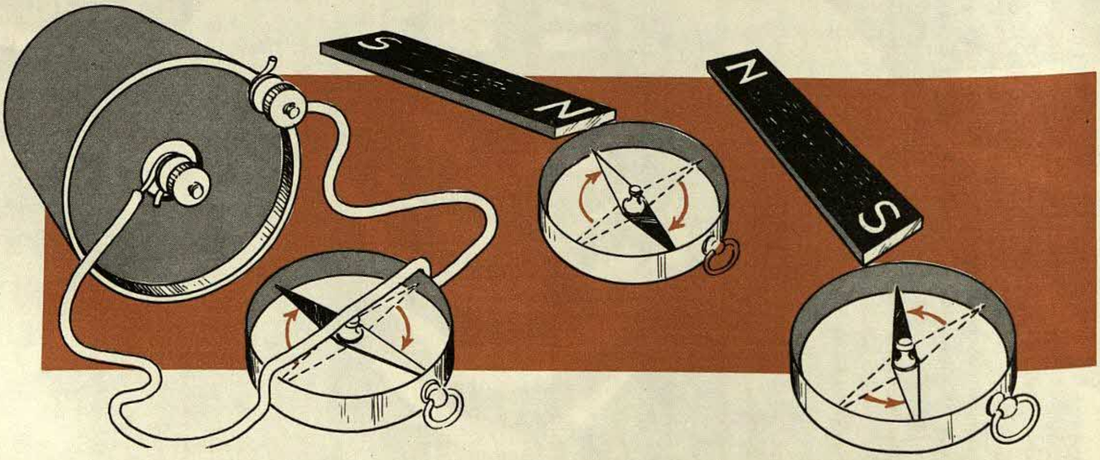
Magnetic Fields

You have probably discovered that when a magnet is brought near an iron nail, the nail is pulled toward it, even though the magnet does not touch the nail. The space around a magnet, in which certain metal objects are affected, is called a ***magnetic field.*** A magnetic field seems to behave in much the same way as a gravitational, or an electric, field. The force exerted in the field is called ***magnetism.*** Magnetic fields are also represented by lines tipped with arrowheads which show the direction of the field. Scientists say the direction of a magnetic field is the same as that of its force on a tiny N pole. Thus, magnetic fields can be mapped as shown on page 149.

Producing Magnetic Fields

If you place a wire over the needle of a compass and force a stream of electrons through it by connecting the wire to a dry cell, the compass needle will move. The needle will also move if you bring a magnet near it, as shown on this page. These observations support the belief that the motions of electrons produce a mag-

Electricity flowing from outside pole (—) to inside pole (+) through wire placed over compass needle causes needle to turn. Reversing direction of electricity reverses direction in which needle turns. Placing a magnet near a compass, as shown, causes needle to turn in direction indicated.



netic field. It is important to remember this generalization as you continue your study.

Refer again to the model used for studying the principle of the inverse square in Problem 1 of this unit. The models representing electric and magnetic fields are identical to it. The principle of the inverse square describes electric and magnetic fields as accurately as it does light.

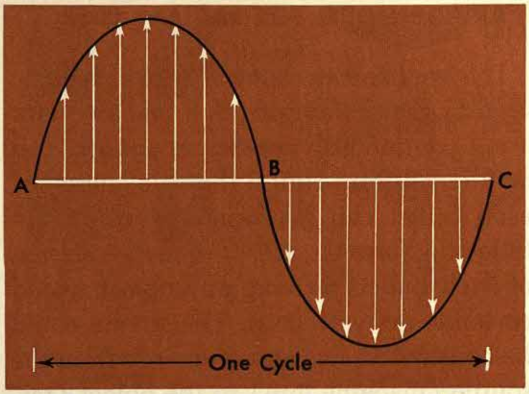
Electromagnetic Waves

You have just learned that both electric and magnetic fields exert a force on certain objects. The assumed direction of the force depends upon the nature of the object in the field that makes the force evident. Although you may not be aware of them, it is assumed that the fields are present at all times around a charged body or a magnet.

Radiant energy is described as ***electromagnetic*** because it acts as if it were an electric and a magnetic field traveling through space. Furthermore, radiant energy exhibits the wave characteristics of cycle, frequency, wave length, and amplitude. For these reasons, the label ***electromagnetic waves*** is also given to radiant energy.

If you could suspend a tiny charge in space filled with radiant energy and could observe its movement, the charge would vibrate back and forth. The electric field would supply the force to move the charge. Its back-and-forth movement would indicate that the direction of the field is constantly changing.

A model of this imaginary situation is shown in column 2. The curved line between A and B represents the electric force at several instants of time in one direction. The straight, horizontal arrows represent the size of the force. Note how the force is zero at A, increases to a maximum, and then decreases to zero at B. A similar action takes place from B to C, but in the reverse direction.



Model of one cycle of electromagnetic wave.

Such alternately changing electric forces would vibrate the imaginary suspended charge. As radiant energy sweeps by the charged particle, its vibration would lead to the inference that the electric field travels first in one direction and then in the other. Thus, radiant energy has fulfilled the conditions necessary to consider it as having the wave characteristics described earlier. These are all identified in the diagram on page 147.

Many observations about radiant energy can be most satisfactorily explained by assuming it to have wave characteristics, even though the energy travels through space without the help of any such medium as ether. For this reason, scientists still use the wave model, although no one knows how radiant energy can possibly travel in waves when there is no medium.

PARTICLE MODEL FOR RADIANT ENERGY

It is well known that a stream of bullets, such as that coming from a machine gun firing continuously, possesses energy. You may recall from Unit 3 that the energy of each bullet can be found by using the following formula: $KE = \frac{1}{2} mv^2$. A stream of such bullets striking any object would certainly do work on it. The stream could be considered a carrier of energy from the source (machine gun) to the object (target). Here, then, is another way to transmit energy through space. And it is much easier to visualize than the wave method.

Using a Particle Model

Sir Isaac Newton, great seventeenth-century English scientist, was one of the most powerful proponents of the particle model for light. He called the light particles ***corpuscles.*** Although his theory, known as the ***corpuscular theory,*** was popular in his time, it failed to be as successful as the wave theory and so was almost completely discarded. In the nineteenth century, a suggestion that light might be a stream of corpuscles would have been considered scientific heresy, yet today, scientists use a particle, as well as a wave, model for radiant energy. However, the particles have been considerably modified from those Newton described. See diagram on page 146.

Quantum Theory of Light

About 1900, Max Planck, a German physicist, was studying the emission of energy from hot objects. He found that he could explain his observations more accurately if he assumed that the energy came off in bunches, or packages, rather than in a continuous stream as required by the wave model theory. He called such packages of energy ***quanta*** (singular, ***quantum***).

The quanta seemed to vary in size. Low-energy quanta seemed to be associated with low-frequency radiation, while high-energy quanta went with high-frequency radiation. Planck determined that the energy of a quantum could be obtained by multiplying the frequency (f) of the radiation by a certain number called a ***constant.*** This value is known as ***Planck's constant,*** and is designated by h. The generally accepted value of h is 6.624×10^{-27} erg-second. Thus the energy of a quantum is obtained by using the formula given below.

$$E = hf$$

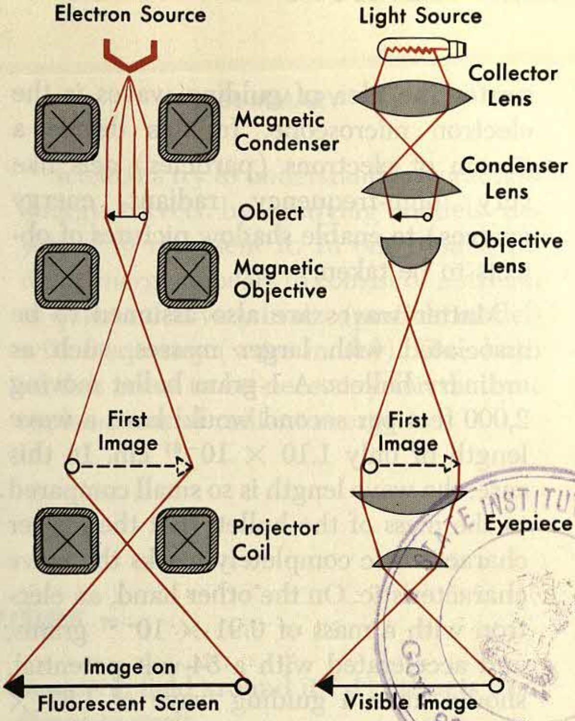
or

$$E = f \times 6.624 \times 10^{-27} \text{ erg-second}$$

This idea was quite startling at the time and was not taken too seriously by most scientists. After all, quanta seemed to be something like Newton's corpuscular theory of light, which supposedly had been discarded.

Photoelectric Effect

About this time, also, it was discovered that electrons were ejected when light fell upon certain material. This phenomenon, called the ***photoelectric effect,*** is used in so-called electric eyes that open doors and turn on drinking fountains automatically. It was very difficult to understand how a wave could strike an object and eject a particle (electron). The wave model seemed totally inadequate.



In electron microscope, left, a stream of electrons has the same effect on a photographic plate that light has in optical microscope, right, reversed for meaningful comparison of image.

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Photons

Shortly after 1900, Albert Einstein, a noted German physicist, suggested that light might be thought of as a stream of bits of energy. He called these ***photons.*** Scientists generally use the term photon when discussing light and quantum with other types of radiant energy. Each photon could have an energy equal to hf in accordance with Planck's work. Thus, when a light photon penetrates a metal and strikes an electron, it gives all its energy to the electron as kinetic energy. If the resulting velocity of the electron is high enough, the electron pops out of the metal to become a photo-electron.

In this way, a particle model can be applied to light and extended to cover all types of radiant energy. The particles are thought of as bits of energy varying in size with frequency, according to Planck's statement that $E = hf$. Many effects of radiant energy can best be explained with such a particle model.

COMBINATION OF WAVE AND PARTICLE MODELS

It seems clear that neither model satisfactorily explains how radiant energy moves from place to place in every instance. Could the models be combined?

Guiding Waves

By 1924, Einstein's idea that mass could be changed into energy and energy into mass was widely accepted. Perhaps, then, matter could be thought of as concentrated energy and energy as very dilute matter. If so, why not consider all moving matter to have wave characteristics (those of radiant energy) and all moving energy to have particle characteristics (mass and velocity)?

The French physicist, Louis de Broglie (LOO-ih duh broh-GLEE) suggested just this in 1924. He believed moving particles (electrons) to have ***guiding waves*** associated with them. He stated that their wave lengths could be found by dividing Planck's constant by the product of the electron's mass and its velocity ($\lambda = h/mv$).

Experiments designed to measure the guiding waves of electrons actually gave not only evidence of their presence, but also values which checked closely with the de Broglie theory. Probably the most commonly known device which demonstrates the idea of guiding waves is the electron microscope. In this device a stream of electrons (particles) acts like very high-frequency radiant energy (waves) to enable shadow pictures of objects to be taken.

Matter waves are also assumed to be associated with larger masses, such as ordinary bullets. A 1-gram bullet moving 2,000 feet per second would have a wave length of only 1.10×10^{-31} cm. In this case, the wave length is so small compared to the mass of the bullet, that the matter characteristic completely masks the wave characteristic. On the other hand, an electron with a mass of 0.91×10^{-27} grams, and accelerated with a 54-volt potential, should have a guiding wave of 1.67×10^{-8}. The wave characteristic here is of such a size that it can influence the electron mass, as is evident in an electron microscope. See diagram, page 153.

Inadequacy of Models

All the models which have been devised and applied to radiant energy are based upon the assumption that it is like something else known. But there is no reason to believe that radiant energy resembles any object of your experience, such as water waves, sand particles, bullets, and so on. Perhaps radiant energy should be thought of as an entirely unique part of man's experience. Certain of its behaviors can be understood best with a wave-characteristic model; others with a photon-particle model. But how can something appear to be both wave and particle at the same time?

Imagine yourself standing in a field of wheat over which the wind is blowing. As you look over the field as a whole, you see waves moving across it. But when you look at the wheat near you, you see the field as composed of individual stalks

Field is made up of individual wheat stalks which move in wave-like formations when wind blows.

A. Devaney

(particles) of wheat. Or perhaps you have watched the wind blow rain during a heavy storm. As you look down the street or across an open field, you can see the waves of rain moving along. But you know that the waves are composed of many raindrops. These two examples show that it is possible to observe something moving as waves even though it is composed of individual parts.

SUMMARY

Scientists try to understand how radiant energy travels by studying models designed to represent it. In one model, radiant energy appears to consist of a stream of quanta that vary in size (particle model) with frequency (wave model). Thus both models seem to be necessary for the best explanations of radiant energy.

Activities

A. *Testing Yourself*

Write the letter of the ending that best completes each statement.

1. The fact that wave motion carries energy (a) has been discovered recently (b) cannot be demonstrated (c) has been known for a long time (d) is inaccurate.

2. The maximum height of a wave is known as (a) frequency (b) wave length (c) amplitude (d) cycle.

3. The distance a wave travels while completing one cycle is known as its (a) frequency (b) wave length (c) amplitude (d) cycle.

4. The velocity of radiant energy is highest in (a) air (b) clear plastic (c) glass (d) water.

5. If a wave with a frequency of 600 cps traveled 1,200 feet per second, its wave length, in feet, would be (a) 720,000 (b) 0.5 (c) 2 (d) none of these.

6. If a rubber rod is stroked with fur, the rod (a) gains a positive charge (b) has an electric field around it (c) has a magnetic field around it (d) attracts iron filings to itself.

7. The same value is always found in (a) Planck's constant (b) a quantum (c) a photon (d) a frequency of a wave.

8. An electron microscope can best be explained with the assumption of (a) guiding waves (b) quanta (c) ether (d) electromagnetic waves.

B. Recognizing Assumptions

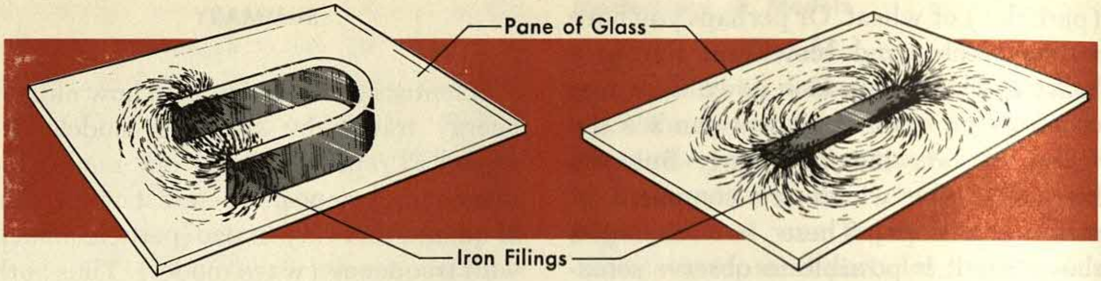
1. The fact that the earth receives light from the sun has been used as evidence to support the generalization that radiant energy travels through space. On your answer sheet, write the letters of the statements below which would have to be accepted as assumptions to make this true.

a. Light travels in the same manner as other types of radiant energy.

b. Much of the space between the sun and the earth is empty.

c. There are periods of daylight and darkness on the earth.

d. There is a sun.



2. It can be observed that when a magnet is placed under a glass plate covered with iron filings, the filings arrange themselves in a definite pattern. From this observation it may be concluded that a magnetic field caused this effect upon the iron filings. On your answer sheet, write the letters of the statements below which would have to be accepted as assumptions to make true the conclusion about a magnetic field described above.

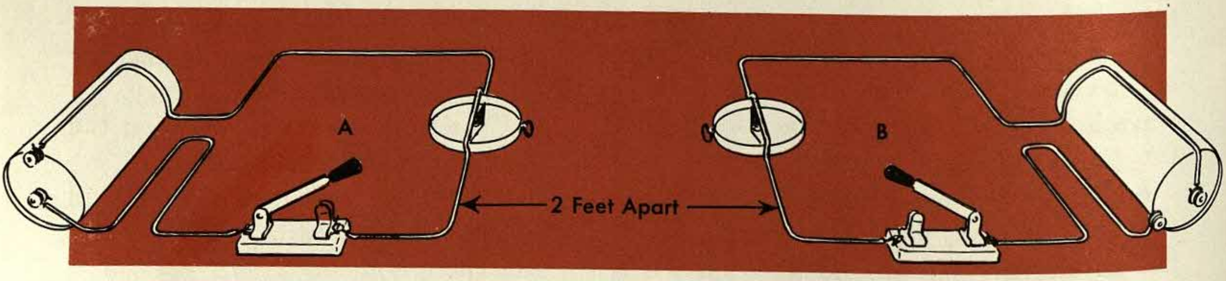
a. A magnetic field was produced by the magnet.
b. Magnets are made of iron.
c. A magnetic field acts through glass.
d. A magnetic field was the only force acting upon the iron filings on the glass plate.
e. Iron filings are different from other kinds of materials.

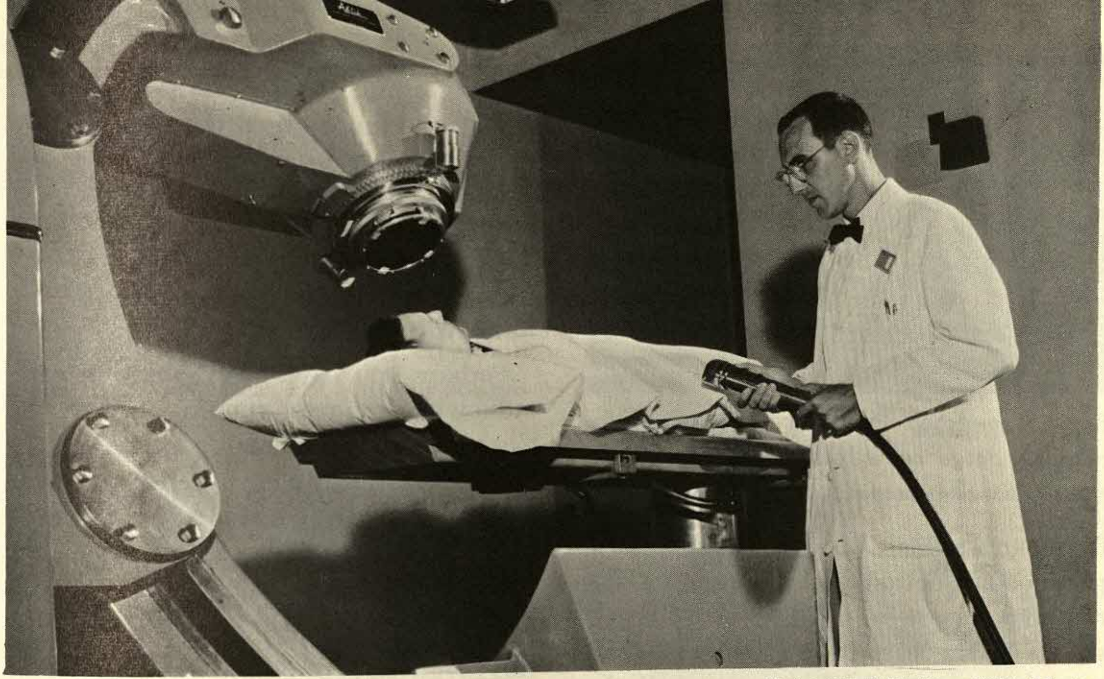
C. *Conducting an Experiment*

With the following setup you can find out if an electric current produces a magnetic field. You can also find out if the direction of the magnetic field depends upon the direction of the electric current.

You will need two compasses, a bar magnet, some copper wire, two dry cells, and two knife switches.

Connect the equipment as shown in the diagram. Make the squares about 18 inches on each side. Note the reversed connections of the dry cells. Now bring the N pole of the magnet near one compass and then the other. Note its effect on the pointers. Do the same with the S pole. Now close the switch briefly on Circuit A and note the effect on both compasses. (Do not keep the switch closed. The effect occurs at the moment you close the switch.) Close switch at B and observe the effect on both compasses.





University of Michigan Medical Center

Radio waves are used to treat cancer. Beam of radiation is directed against affected area.

PROBLEM 3: HOW ARE RADIO WAVES USED?

In Problem 2, you learned that some of man's experiences with radiant energy can best be understood by applying a wave model and some by applying a particle model. Both models will be used in explaining man's use of radio waves. When used for communication in radio, television, and radar, the wave model seems adequate. But when it is used for purposes of heating, the wave model alone is inadequate. Some attention must be given to the particle model. The explanations that follow will be based upon the two models studied in Problem 2.

THE RADIO WAVE SPECTRUM

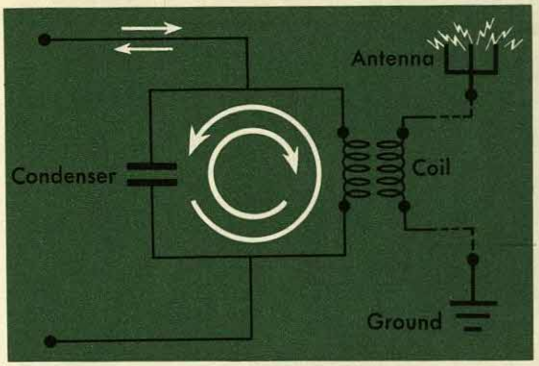
Radio waves have lower frequencies and less energetic quanta than most of the other waves. Their frequencies range from about 10,000 cps to 1.5×10^{12} cps. The energy of their quanta ranges from about 6.624×10^{23} to 10×10^{-15} ergs. What would be the range of their wave lengths?

RADIO WAVES FOR COMMUNICATION

Radio waves have proved to be excellent for communication. They travel rapidly, can be sent long distances, and require no physical connections such as wires between sender and receiver. They are ideal for mass communication.

Producing Radio Waves

If electrons are made to flow in and out of a capacitor, first in one direction and then in the opposite direction, a low-



Properly matched coil and condenser allow relatively large currents to circulate at same rate in parallel resonant circuit, above.

frequency radiant energy wave may be produced. Electrons in motion create the required magnetic field, and electrons stored in the capacitor produce the required electric field. The rate at which the electrons change their direction of flow into, and out of, the capacitor determines the frequency of the radiant energy wave they produce.

A device to carry on the process described above is known as a ***tuned circuit.*** It is widely used by radio broadcasting stations to produce their radio waves. Although there are other ways of causing electrons to create radiant energy waves, the operation of the tuned circuit serves to illustrate how electrons produce low-frequency radiant energy waves.

Spark Wireless

Perhaps you have heard static in your radio when you were running the vacuum cleaner, or when someone was using an electric razor. Any electrical device which produces sparks causes static in most radios. Lightning, a huge natural electric spark, may cause so much static that the program to which the radio is tuned cannot be heard at all.

The first radio waves to be broadcast were produced by a series of electric sparks. Although these waves could be received at some distance from the place where they were produced, voice and music could not be broadcast with them. Instead, they were used to broadcast messages by the Morse Code. In this code,

Morse Codes

International Morse		*American Morse*	
A •—	N —•	A •—	N —•
B —•••	O ———	B —•••	O • •
C —•—•	P •——•	C •• •	P •••••
D —••	Q ——•—	D —••	Q ••—•
E •	R •—•	E •	R • ••
F ••—•	S •••	F •—•	S •••
G ——•	T —	G ——•	T —
H ••••	U ••—	H ••••	U ••—
I ••	V •••—	I ••	V •••—
J •———	W •——	J —•—•	W •——
K —•—	X —••—	K —•—	X •—••
L •—••	Y —•——	L ——	Y •• ••
M ——	Z ——••	M ——	Z ••• •

letters of the alphabet are represented by short and long sounds called ***dots*** and ***dashes.*** Spark wireless, as this kind of broadcasting was called, did not prove satisfactory for several reasons. It could be used only for code. The waves sent out from various stations interfered with each other. They could be received at only short distances from the sending station.

Vacuum Tubes

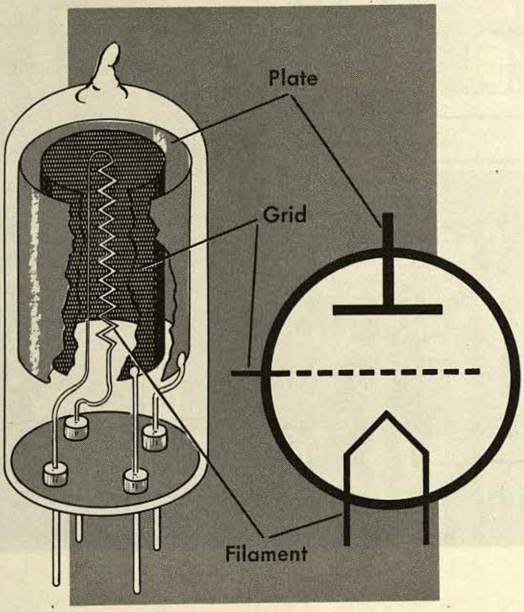
The limitations of spark wireless were overcome by the invention of vacuum tubes similar to those used in modern radios. These tubes have made it possible to control the flow of electrons so that radio waves are produced. The waves can be used to broadcast voice and music. These tubes have also made it possible to build radio receivers that can detect radio waves sent from great distances.

Transistors

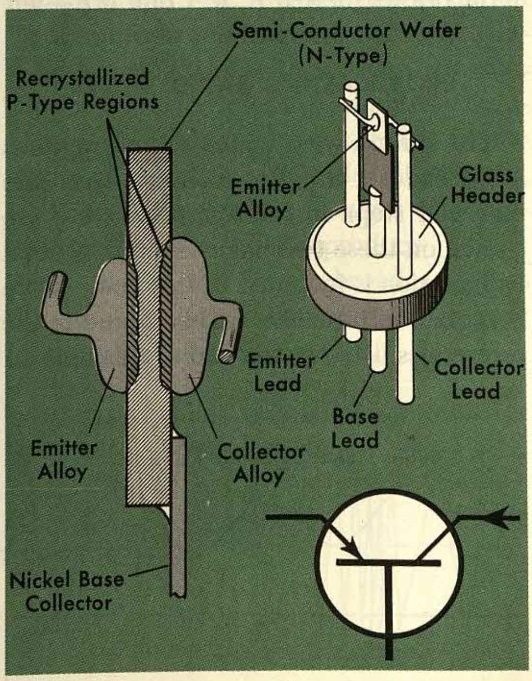
In 1948, three scientists of the Bell Telephone Laboratories announced the invention of the ***transistor.*** The transistor is a tiny device that will perform many of the functions of the vacuum tube. It requires very little energy to operate, has a long life, is rugged, and occupies little space. Transistors are being substituted for vacuum tubes in many appliances and result in a saving of space, weight, materials, and electrical energy.

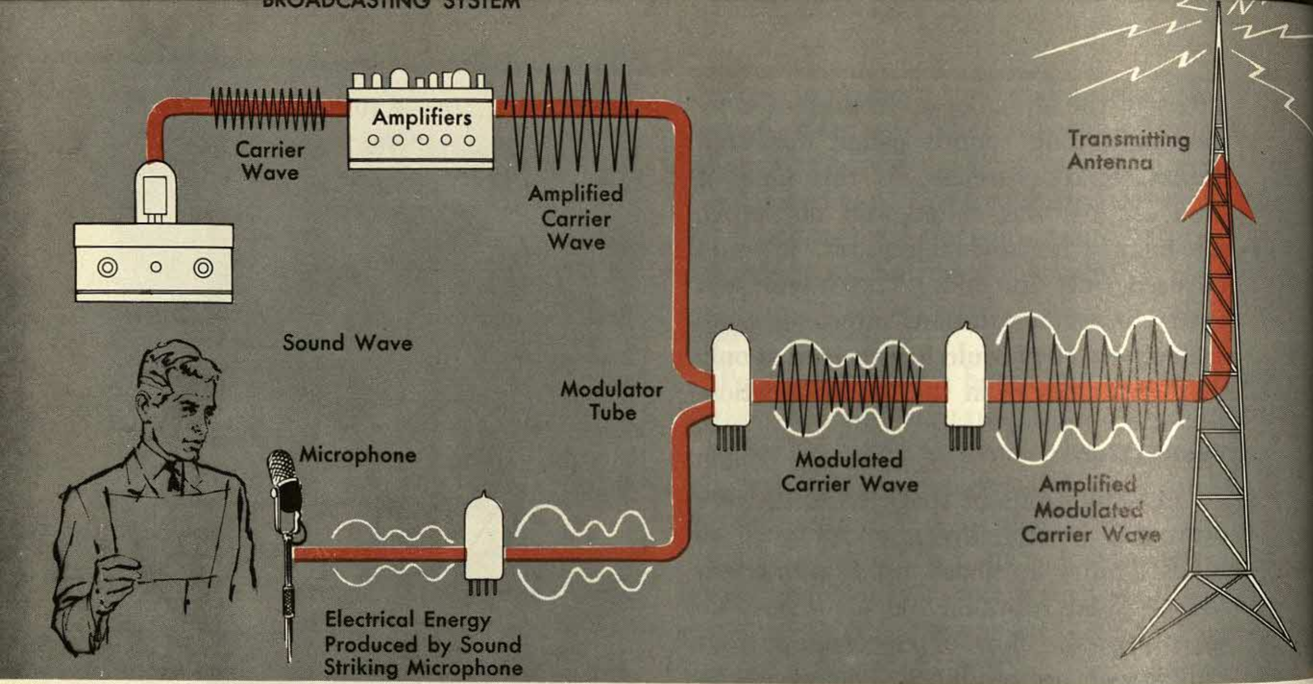
The science and technology dealing with the control and movement of electrons in devices such as vacuum tubes and transistors is known as ***electronics.*** Thus, when you study radio, television, and other applications of these devices, you are studying electronics. In the ex-

TRIODE TUBE



JUNCTION TRANSISTOR





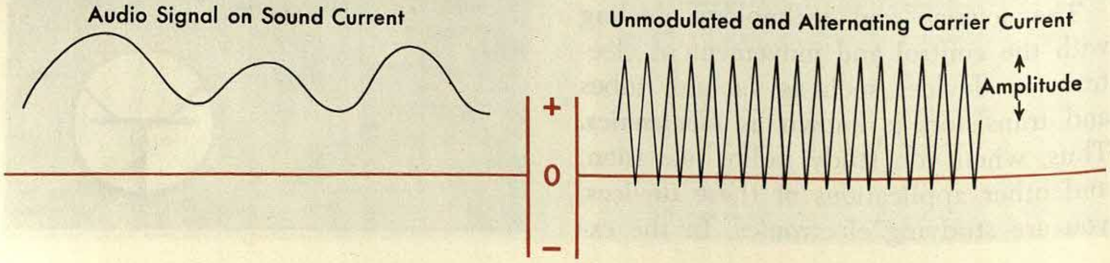
planations that follow, a transistor can be substituted in many cases, but not in all, for a vacuum tube.

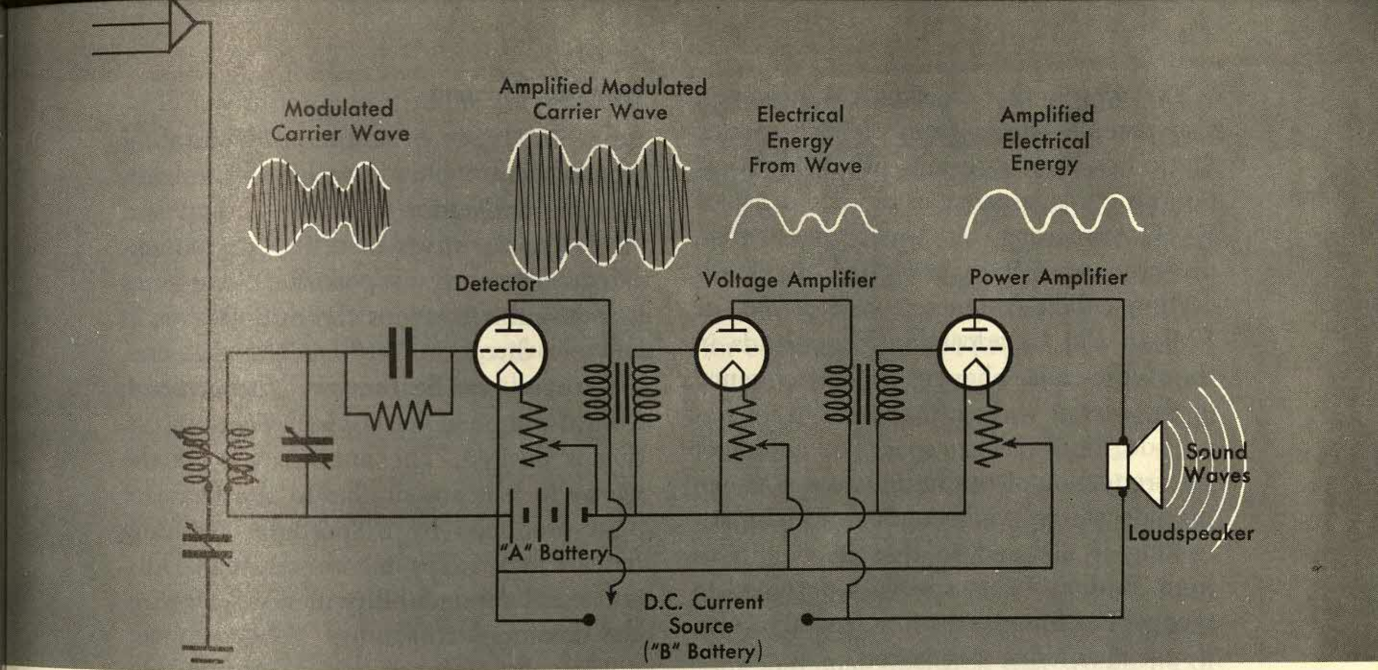
BROADCASTING RADIO WAVES

The station from which radio programs are broadcast is called a ***transmitter.*** The essential steps in radio broadcasting are shown on these two pages. Only a general explanation is included in this book. More complete information will be found in the references listed at the end of this unit.

Carrier Wave

In the diagram, you will see that after the ***carrier wave*** is produced, it is increased in power, or ***amplified.*** This is done by controlling electrons in vacuum tubes. The carrier wave is so named because it is the basic radio wave that carries speech and music from the station to the listener. The way in which speech, music, and other sound effects are put upon the carrier wave is shown in the diagram. The performers in the studio direct their speech or music toward a microphone.


Audio Signal on Sound Current
Unmodulated and Alternating Carrier Current
Amplitude
+
0
–


Modulated Carrier Wave
Amplified Modulated Carrier Wave
Electrical Energy From Wave
Amplified Electrical Energy
Detector
Voltage Amplifier
Power Amplifier
Sound Waves
Loudspeaker
"A" Battery
D.C. Current Source ("B" Battery)

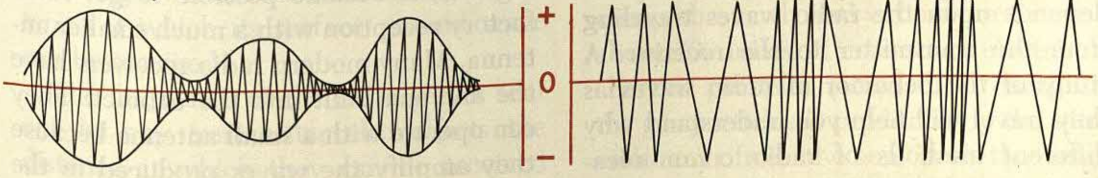
The sound causes the microphone to develop an electric current. This electric energy is amplified and, by a process called ***modulation,*** mixed with the carrier wave being developed at the radio station. The carrier wave is then amplified again, directed to the ***antenna,*** and is allowed to escape into space. Because it is a radiant energy wave, it travels about 186,000 miles per second. Thus speech and music, when broadcast by these waves, can encircle the earth in a fraction of a second.

AM and FM Broadcasting

There are two types of radio broadcasting—AM and FM. AM is an abbreviation for ***amplitude modulation.*** All radio stations broadcasting with frequencies from 550 to 1500 kilocycles use amplitude modulation. In AM, the sounds made in the studio change the amplitude, or strength, of the radio wave. The changes of amplitude make your radio reproduce in your home the sounds being broadcast from the radio station. They come out of your loudspeaker as sound waves.

AM Wave Carrier Current Modulated by Sound Current

FM Wave Frequency Modulated Carrier Current



Every radio that receives AM, however, also receives static from electric sparks. Static has been a serious problem. In attempting to overcome, or remove it, Major E. H. Armstrong, an American scientist, invented an entirely new type of broadcasting called ***frequency modulation***, or FM. In FM broadcasting, the sounds in the studio cause changes in the frequency of the carrier wave rather than in its amplitude. Since electric sparks do not affect the frequency of the radio wave, FM can provide static-free reception. FM broadcasting is planned so that its fidelity is high. Radio sets are specially designed to receive FM broadcasts. For special results, a special antenna is required.

Stereophonic broadcasting and receiving have been permitted since 1961. In this system, sounds are recorded for broadcast by two or more microphones and reproduced by two or more sound systems and separate loudspeakers.

The sound accompanying television programs is broadcast by FM. The television receiver, therefore, contains an FM receiver which reproduces the sound broadcast from the television studio. The manner in which the television picture is broadcast and received is described on pages 190–195 of this unit.

RECEIVING RADIO WAVES

The success of wireless communication depends upon the radio waves traveling from the transmitter to the receiver. A study of the behavior of radio waves as they travel will help you understand why different methods of radio communication are used.

Types of Antenna

Several types of antennae (plural of antenna) have been developed for wireless communication in order to send and receive radio waves at different frequencies as efficiently as possible. Sometimes it is desirable to focus the radio waves in only one direction. With such an antenna, the waves can be focussed, or ***beamed***, toward the point with which communication is desired. The antenna directs the waves in a beam similar to the beam of light produced by a spotlight. Beaming radio waves helps insure maximum distance and dependability of two-way wireless communication.

The effectiveness of receiving radio waves depends upon the design and the manner in which antennae are installed. For example, the antennae used on television receivers are designed to provide the best possible reception on several channels. Best results are usually obtained in places some distance from the transmitter, when the antenna is as high as possible and pointed toward the station being received. Often a small motor is installed on the antenna mast so that the antenna can be rotated for best results from each station being received.

The earlier radios used a long, single wire high above the ground for an antenna in order to get satisfactory reception. As improvements were made in radio receiving sets, it became possible to get satisfactory reception with a much smaller antenna. Many modern radio receivers have the antenna built into the cabinet. They can operate with a small antenna because they amplify the waves produced in the antenna as much as 500,000 times.

When radio waves strike the antenna, they produce similar waves in the antenna, which are then amplified by an electron tube. Other tubes then separate the other electric waves produced by the program at the studio from the carrier wave. The electrical energy is amplified and is finally led to a loudspeaker, which transforms it to sound. Thus the program produced in the studio is reproduced in your home.

Ground and Sky Waves

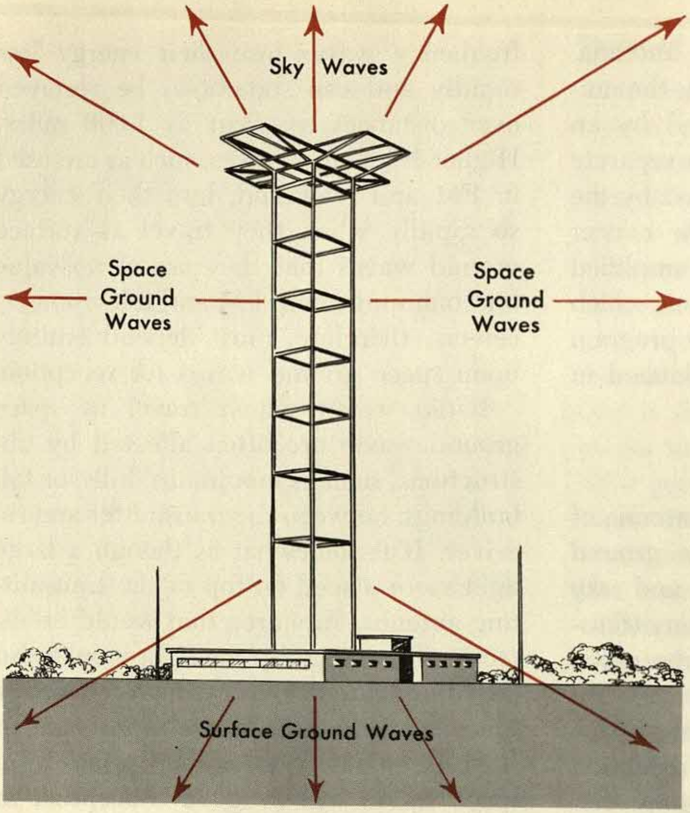
The radio waves leaving the antenna of a transmitter travel as ***surface ground waves, space ground waves,*** and ***sky waves.*** The radio waves sent by any transmitter normally travel in all three ways, as shown on page 164. Home radio receivers ordinarily depend upon the space and surface ground waves for reception from near-by broadcasting stations. Reception from distant stations is obtained only from sky waves.

Surface ground waves lose their energy rapidly as they travel through the surface of the earth. They become weaker and weaker, until finally they can no longer be received by home radios. The surface ground waves lose their energy less rapidly when they travel through water than through land. The land surface also varies in its ability to conduct these waves. Thus, the nature of the surface of the earth surrounding a transmitter determines the distance at which its surface ground wave can be received.

The frequency of the radio waves sent out by any transmitter also affects the distance at which they can be received as surface ground waves. The lower-frequency waves lose their energy less rapidly and can sometimes be received over distances as great as 1,000 miles. Higher-frequency waves, such as are used in FM and television, lose their energy so rapidly when they travel as surface ground waves that they are of no value for communication. FM and television receivers, therefore, must depend entirely upon space ground waves for reception.

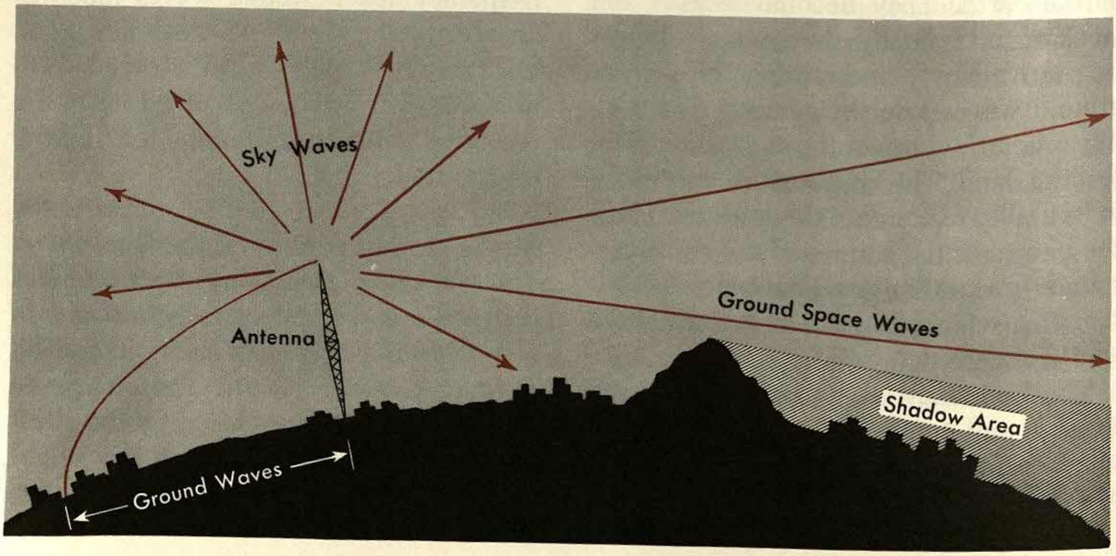
Radio waves which travel as space ground waves are often affected by obstructions, such as mountains, hills, or tall buildings, between the transmitter and receiver. It is somewhat as though a large light were placed on top of the transmitting antenna. Any area that would be directly illuminated by the light would also be "illuminated" by the high-frequency space ground waves from the antenna. In such illuminated areas, reception from space waves will be good. Reception in any area shadowed by obstructions may be poor. Reception in such a location is known as ***fringe area*** reception. The curvature of the earth also affects high-frequency space ground waves much as an obstruction such as a mountain does. For these reasons, FM and television programs usually are best received when the receiving antenna is "illuminated" by the transmitted signal.

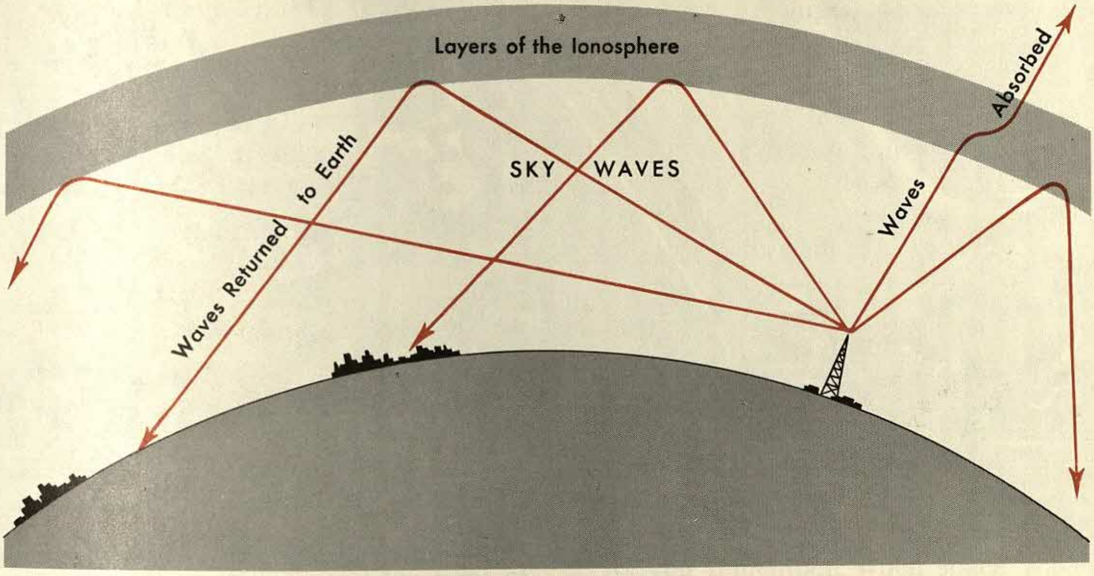
Sky waves are affected by a layer of the earth's atmosphere called the ***ionosphere.*** The ionosphere begins at about 60 miles above the earth and extends outward to about 200 miles. It consists of electrically charged particles (ions). The charge on the gas particles is produced by the ultraviolet rays from the sun. Both the height and composition of the ionosphere change



Paths of the three types of radio waves are shown at left. Behavior of each of these waves depends upon the frequency of the waves and the nature of the material through which they travel. Successful wireless communication depends upon effective use of each type of the waves shown.

Radio waves used in broadcasting FM and television travel in straight lines and are not reflected back to earth. Only viewers between antenna and shadow area can pick up the signals directly.





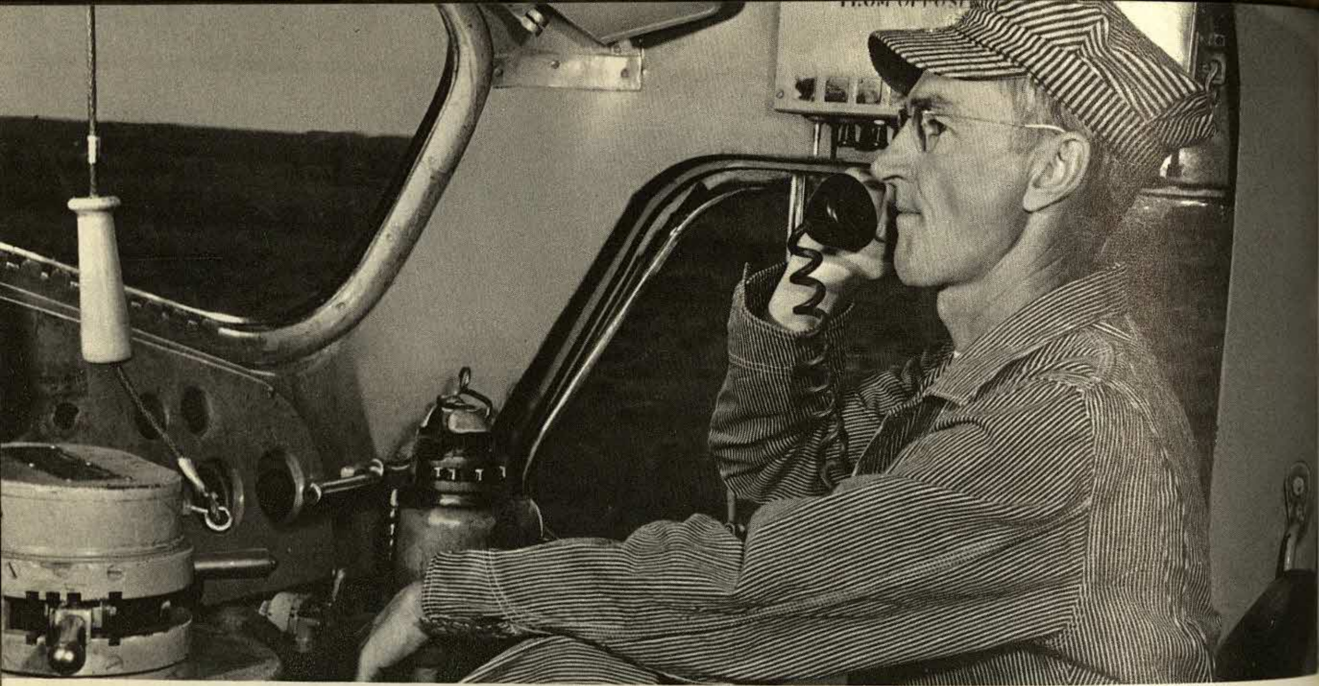
Some sky waves are absorbed by the ionosphere and others are returned to earth by it, as shown in the diagram. Frequency of waves and condition of atmosphere determine what happens.

from daylight to darkness, with the seasons, and with changes that take place on the surface of the sun.

The effect of the ionosphere on sky waves of regular AM radio stations is shown on this page. During the day, the reception of stations is limited to ground waves which cover a distance of from 50 to 200 miles, depending on the nature of the earth's crust between the transmitter and receiver. As the sun goes down, the character of the ionosphere changes, and the sky waves may return to the earth from the ionosphere and thus increase the range. For this reason, long-distance reception is possible with a standard radio at night, but impossible during the daytime. The sky waves of short-wave radio stations are often returned to the earth from the ionosphere as shown on this page. In fact, they may go back and forth between the ionosphere and the earth several times before they become too weak to be received. For this reason, the sky waves from short-wave transmitters provide the most satisfactory wireless communication for distances greater than 1,000 miles. Transoceanic radio broadcasts and telephone service are largely carried on with the sky waves from short-wave transmitters. The sky waves of FM and television transmitters are usually absorbed by the ionosphere, and they are not useful for long-distance reception.

Fading of Radio Reception

Radio reception which depends upon sky waves sometimes changes strength so rapidly that speech is difficult, if not impossible, to understand. This is known as



Santa Fe Railway

A guided carrier system permits the railroad engineer to telephone directly from his engine cab.

fading. Fading may occur when two or more sky waves follow different paths from the transmitter to the receiver. When all sky waves arrive at the receiver so that their electric and magnetic fields reach a maximum value at the same instant, reception is strong and clear. If, for some reason, one sky wave reaches the receiver so that its fields are out of step with those of the other sky waves, the program fades away completely.

Sky waves are seriously affected by any great disturbance of the earth's magnetic field. Such disturbances are called ***magnetic storms.*** A magnetic storm may last several days, during which time long-distance communication is difficult or, if the storm is severe, impossible. Sudden disturbances on the sun may also cause a complete fade-out of sky waves, making communication by sky waves impossible.

TWO-WAY WIRELESS SYSTEMS

When wireless communication can be carried on between two locations, the systems used are called ***two-way systems.*** Four main types of two-way wireless communications are used: (1) ***guided-carrier,*** (2) ***medium-frequency,*** (3) ***very high-frequency,*** and (4) ***microwave.***

Guided-Carrier Systems

Railroads and electric power companies often use guided-carrier communication systems. In such systems, radio transmitters and receivers are used, but the waves carrying the signal are conducted by the power line, the railroad track, or the telephone and telegraph lines along the track. Although such a system is not strictly a wireless system, it is classed as a wireless system because the radio waves are guided over conductors that were not constructed for that purpose.

Medium-Frequency Systems

Medium-frequency two-way systems usually operate at frequencies somewhere between 2,000 to 4,000 kilocycles. They consist of an AM or FM transmitter, a receiver, and a suitable antenna located at each of the two places between which communication is being carried on. Both ground waves and sky waves are used. The ground waves provide consistent communication up to distances of fifty miles during the day. At night, sky waves make communication possible anywhere from 300 to 800 miles, depending upon frequency, time of year, and locations of transmitter and receiver.

Medium-frequency systems are used by some railroads, by aircraft, and for maritime communications both at sea and on rivers, harbors, and the Great Lakes. These systems are also very useful in the event of disasters such as hurricanes, which disrupt the regular-line communication facilities.

Very High-Frequency Systems

Very high-frequency systems differ from medium-frequency systems primarily in the frequencies of radio waves used. They operate on frequencies ranging from 30 to 162 ***megacycles*** per second. A megacycle is a million cycles. Because of the high frequencies used, communication is largely dependent upon the ground waves. The distance of communication, therefore, ranges from 25 to 75 miles, depending upon the location of the stations, the nature of the earth's surface over which the signal must travel, and the exact frequency being used. These systems are used for short-distance communication by fire departments, police departments, the Forest Service, railroads and other forms of transportation.

Microwave Systems

Microwave systems cannot be used for communication over distances as great as the other two-way systems described. Their range is limited because they operate at extremely high frequencies of from 300 to 5,000 or more megacycles per second. At such high frequencies, only the space wave can be used effectively for communication.

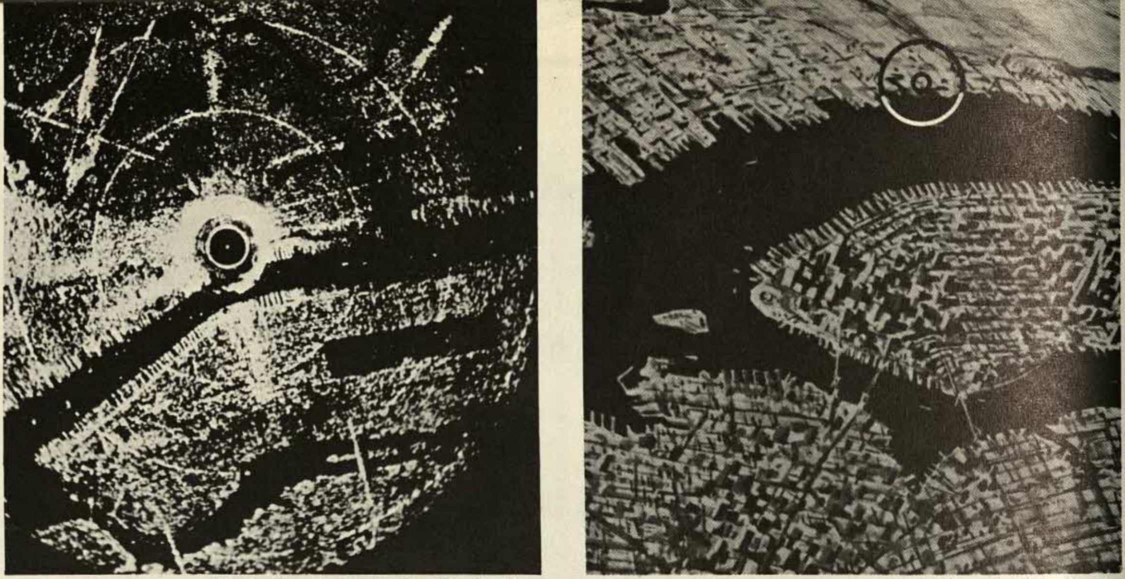
As you remember, when space waves are used, reception is poor or impossible below the horizon of the transmitter. However, microwaves can be beamed toward the receiver, reception does not vary at any time, and there is practically no static. Furthermore, it is possible to have a number of microwave systems operating throughout the country without interfering with each other, since the range of each transmitter is so limited.

RADAR

The name ***radar,*** a contraction of the phrase "Radio Detection and Ranging," is given to any device that discovers and determines the position of objects by means of radio waves.

How Radar Works

In a radar system, short ***pulses,*** or spurts, of high-frequency radio waves, each about a millionth of a second long,



Massachusetts Institute of Technology

Port of New York Authority

Parts of New York and New Jersey, as they appear on a radar screen, are shown above, left. An aerial photograph of the same area is at right. The identical center is marked in each photograph.

are sent out through space at the rate of a few thousand each second. Thus, there is a pause for a few thousandths of a second between pulses. If the radio waves strike an object, some of them return to the place from which they were sent. During the pause between pulses, a radar receiver detects the waves as they return from the object. If the radar antenna is slowly rotated, a picture like that above, left, can be obtained with special equipment in the radar receiver.

Radar at Work

With radar, ships have been discovered, tracked, fired upon, and sunk without having been seen. Targets have been located and bombed by planes through an overcast of heavy clouds.

Radar makes it possible for a captain to pilot his ship more safely through dangerous waters in deepest fog. In an emergency at sea, radar is invaluable. On one occasion, a ship 200 miles at sea reported that one of its seamen had been taken seriously ill and needed to be hospitalized immediately. Though there was a heavy fog at the time, a Coast Guard pilot easily located the ship by radar, landed beside it, and flew the sailor to the hospital for the treatment he urgently needed.

Radar is almost a necessity to airplanes during fogs. In an airplane equipped with radar, the pilot has before him, in darkness or in fog, a view of everything around him, including other planes.

Radar is also a necessary part of the equipment at a modern airport. Take the case of an airport whose runways cannot be seen because the fog is so dense. Planes are due to land at any moment. With their radar equipment, the men in the control tower can tell exactly where every plane in the vicinity is—at what distance from the airport, and at what altitude each plane is flying. By radio communication with the pilots, the planes may be "talked in" to a landing even though the airport cannot be seen clearly by the pilot.

OTHER USES OF RADIO WAVES

The energy content of a radio wave is not of primary concern for purposes of communication. Enough energy must reach a receiver to be detected, but the most important characteristics of the radio wave for communication are its velocity and its ability to reach remote places through the medium of space. Industry and medicine have found some uses for radio waves that depend more upon their energy content.

Radio Waves in Industry

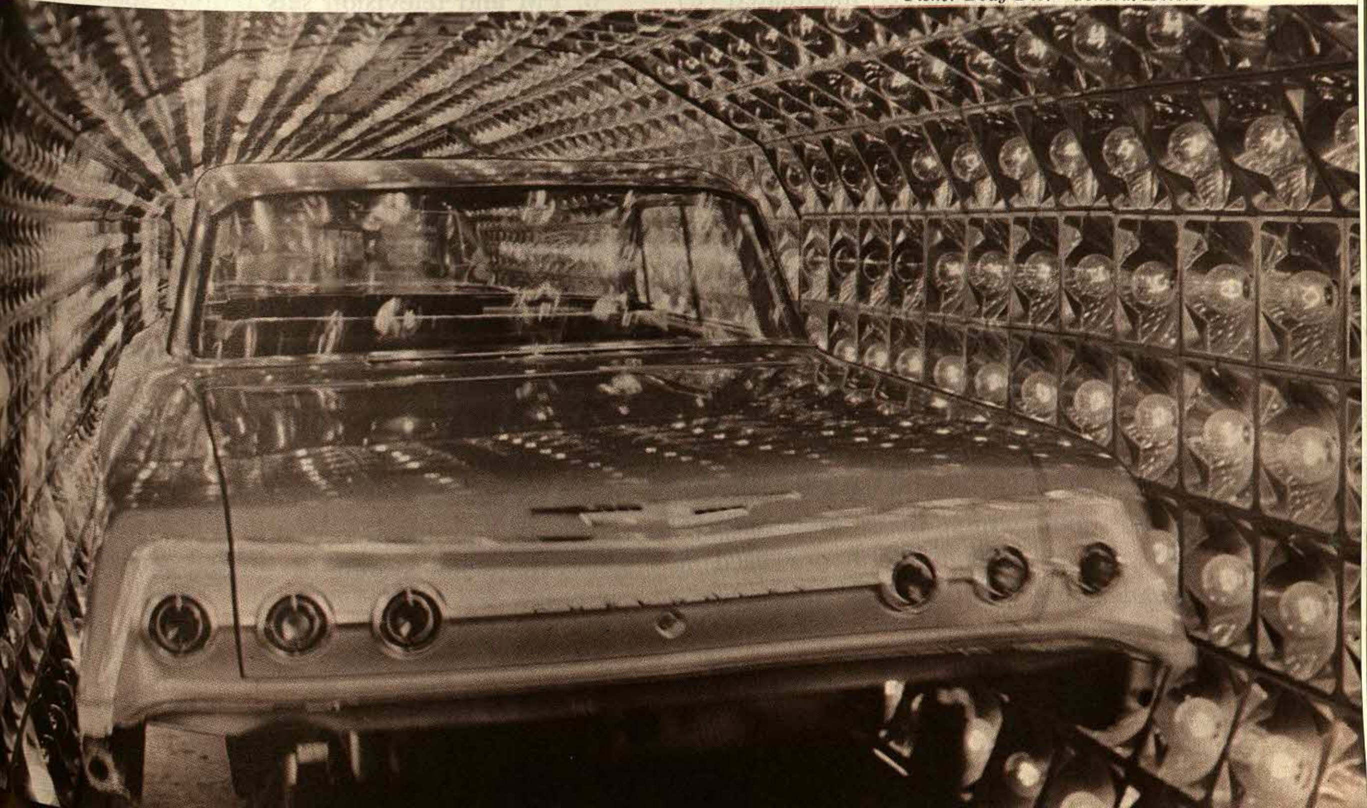
Low-frequency radio waves are used for heating many different kinds of materials. Metals can be heated to any depth, or melted as desired. With older methods of heating, metal sheets could be covered with tin at the rate of 200 feet per minute. By heating with radio waves, they can be covered at the rate of 1,000 feet per minute. The heat required in the manufacture of articles of plastic, such as small radio cabinets, dishes, and combs, can be conveniently produced with radio waves. Food can be cooked with radio waves in a much shorter time than by the usual methods. Heat is produced throughout the food, although the oven itself is cold.

Radio Waves in Medicine

Radio waves are often used to produce heat in the human body in the treatment of body ailments. A large rubber-covered wire is placed around the part of the body where heat is wanted. Radio waves of the

Hundreds of electric lamps in a long tunnel provide the radiant heat which dries paint on autos.

Fisher Body Div.—General Motors



proper frequency are then passed through the cable, producing heat where the body is surrounded by the cable. It is possible in this way to increase the temperature of any part of the body by using radio waves to produce heat.

SUMMARY

Radio waves are used in many different ways. Wireless communication depends upon radio waves traveling from the transmitter to the receiver with sufficient strength to enable the receiver to operate satisfactorily.

Radar depends upon radio waves returning at a known speed from objects they strike. It is thus possible to locate and determine the distance of an object from a radar unit.

Radio waves of certain frequencies can also be used for producing heat.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. When the strength of a radio wave is increased by the use of electron tubes, the wave is (a) amplified (b) modulated (c) detected (d) decreased.

2. When short pulses of radio waves are used to determine the location and distance of an object from some point, the system is known as (a) radar (b) loran (c) shoran (d) electronics.

3. A radio broadcasting system in which speech and music change the frequency of the wave is known as (a) AM (b) PM (c) FM (d) FCC.

4. The frequency of a radio broadcasting station is determined by (a) the rate at which the electrons move back and forth in a tuned circuit (b) the electric power upon which the station operates (c) the kind of microphones used in broadcasting (d) the height of the transmitting antenna above the radio station.

5. Radio waves that travel through the atmosphere near the surface of the earth are called (a) sky waves (b) space waves (c) surface ground waves (d) modulated waves.

6. FM and television sets require special antennae because they depend upon (a) modulated waves (b) sky waves (c) surface ground waves (d) space waves.

7. Extremely long-distance radio communication is possible because (a) a special kind of modulation is used (b) the ionosphere returns the sky waves to the earth (c) the ionosphere absorbs the sky waves (d) surface ground waves are used.

8. A two-way communication system using radio receivers and transmitters, but sending the wave along conductors such as rails which were installed for other purposes, is called a (a) microwave system (b) very high-frequency system (c) medium-frequency system (d) guided-carrier system.

B. Solving a Problem

Suppose you were reading a newspaper account of an open-air concert which had just been held in your community. The newspaper story stated that the concert had been broadcast to people overseas. The author of the article said that because of the marvels of modern science, people in England actually heard the music over their radios before many of the people in attendance at the concert heard it. You become interested in finding out how it was possible for people in England to hear a concert before those in attendance.

PART 1

Following are a number of problem statements. On your answer sheet, write the number of the best statement of your problem.

1. How is music broadcast by radio?
2. Why was the concert broadcast to people overseas?
3. How is it possible for music to reach people in England before it reaches some people in the audience?

PART 2

Following is a list of activities which might help you solve the problem you selected from the preceding list. On your answer sheet, write the numbers of those activities which you believe would help you most in solving the problem.

1. Interview the conductor of the orchestra which played the concert.
2. Read about sound and radio in your science book.
3. Build a small radio.
4. Interview a radio engineer.
5. Interview your science teacher.
6. Interview your neighbor, who is a musician.
7. Observe a film dealing with the way musical instruments produce sound.

PART 3

Following is a list of some of the facts which you might have gathered by performing the activities selected from Part 2. On your answer sheet, write the numbers of those facts which you need to solve your problem.

1. Radio waves travel about 186,000 miles per second.
2. Radio waves are modulated by the sounds being broadcast.
3. Radio is a modern, rapid means of communication.
4. Sound travels about one-fifth of a mile per second.
5. A microphone is used in broadcasting.
6. Some radios need special antennae.

PART 4

On your answer sheet, write the number of the statement below which is the best conclusion to the problem, based upon the statements selected from Part 3.

1. It is possible for people in England to receive radio broadcasts from the United States.
2. The statement in the newspaper is true because of the great difference in speed between sound and radio waves.
3. The statement is false because sound cannot travel such great distances.
4. The truth of the statement cannot be judged because it is impossible to find out where the people in England, who listened to the program, lived.

Standard Oil Co. (N. J.)

PROBLEM 4: HOW IS LIGHT USED?

It is only natural that man should have been aware of light longer than any other type of radiant energy, for light makes his vision possible. And yet light is invisible. This fact makes light an unusual type of energy.

THE LIGHT SPECTRUM

Light makes up only a small part of the total spectrum of radiant energy. Light includes the frequencies between about 3.75×10^{14} cps to 7.5×10^{14} cps. Because of its high frequency, the photon energy is much higher than that of radio waves. The photons range in energy from about 25 to 50×10^{-13} ergs. To avoid using large numbers when studying light, its very short wave length is given in either of two special units. One is a ***millimicron*** ($M\mu$), which is one billionth (1/1,000,000,000) of a meter. The other is an ***angstrom*** (A), which is $\frac{1}{10}$ of a $M\mu$. In these terms, light is that radiant energy with a wave length ranging from about 400 to 800 $M\mu$, or 4,000 to 8,000 A.

Natural and Artificial Light

Light that comes directly from the sun and from distant stars is ***natural light.*** Because very little light from distant stars is received, the sun is the earth's most important natural light source. Moonlight is also reflected sunlight.

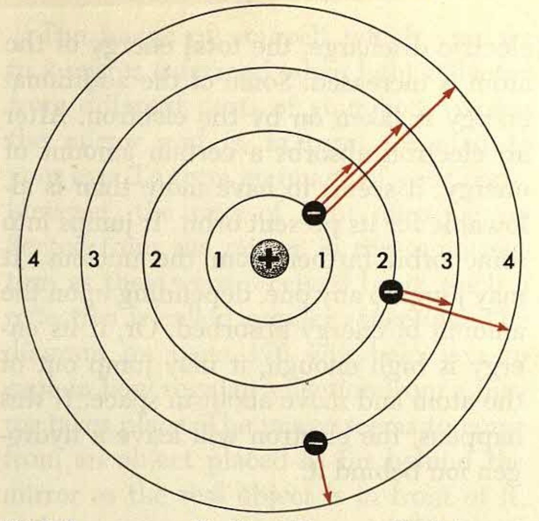
Light not obtained directly from the sun is called ***artificial light.*** For many centuries the only way man could produce artificial light was to burn substances such as oil, candles, and gas which contain carbon. Such light tends to give a yellowish-red color to many objects it illuminates.

It is no longer necessary to burn materials in order to produce light. It was discovered that when electricity is passed through a wire of ***tungsten*** (a metallic element), the wire becomes extremely hot and gives off light. A substance that gives off light when it is heated ***white-hot*** is said to be ***incandescent.*** Electric lamps are, therefore, called incandescent lamps.

Both flames and incandescent wires depend upon heat to produce light. But producing light by the use of heat is inefficient. It is estimated that less than ten percent of the electricity used by an incandescent lamp actually produces light. The rest is used to produce heat needed.

The ***fluorescent*** lamp is more efficient than the incandescent lamp because almost twenty percent of the electricity required to operate it is used in producing light. The diagram on this page shows how the fluorescent lamp produces light.

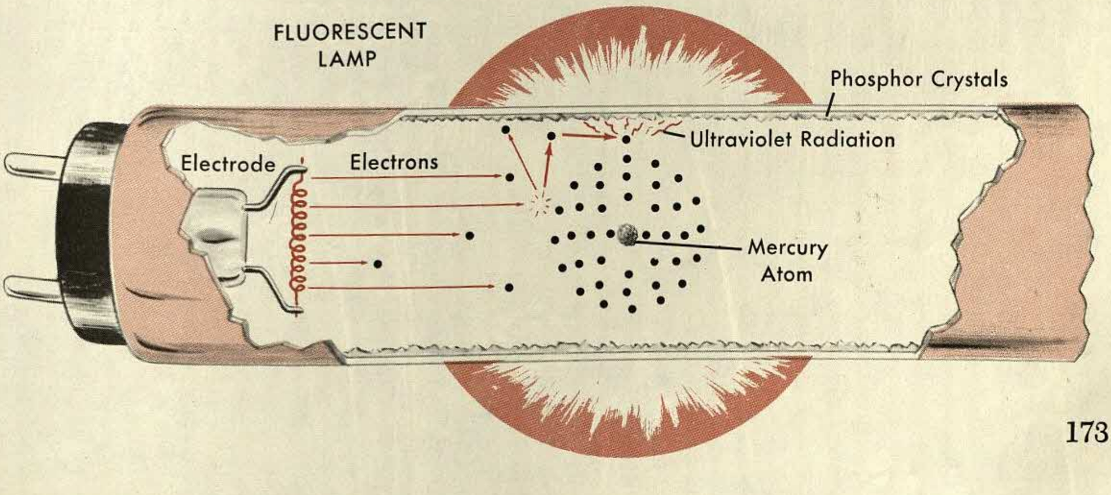
BOHR-STONER ATOM MODEL



High-Frequency Radiant-Energy Model

For one explanation of the way light, as well as several other types of radiant energy, is produced, you will study the Bohr-Stoner atom model of hydrogen because hydrogen has the simplest model. A schematic representation of such a model is shown on this page.

Under ordinary temperature conditions, the electron seems to travel in orbit number 1. This orbit represents the lowest energy level, while the others represent higher levels. No radiant energy is emitted by an electron as it circulates in an orbit. But if energy is added to the atom by some means such as heating, or by an



electric discharge, the total energy of the atom is increased. Some of the additional energy is taken on by the electron. After an electron absorbs a certain amount of energy, it seems to have more than is allowable for its present orbit. It jumps into some orbit farther from the nucleus. It may jump to any one, depending upon the amount of energy absorbed. Or, if its energy is high enough, it may jump out of the atom and move about in space. If this happens, the electron will leave a hydrogen ion behind it.

Excited Atoms

Hydrogen atoms in which electrons occupy an orbit other than number 1 are called ***excited atoms.*** In any sample of energy radiating hydrogen gas, there are billions and billions of excited hydrogen atoms. It is assumed that there will be some with electrons in every possible energy level. For reasons not clearly understood, an electron in some outer orbit will return to some inner orbit nearer the nucleus. In so doing, the electron must release some energy because it would have too much to occupy a lower-energy orbit. It emits the surplus energy as a photon. An electron moving from orbit 6 to orbit 2 would result in a photon of different energy than one moving from orbit 3 to 2. Thus the billions of electrons moving from various higher energy-level to lower energy-level orbits account for the radiant energy emitted by excited hydrogen atoms. An explanation of the production of high-frequency radiant energy based upon the Bohr-Stoner atom leads to a particle model of radiant energy. No attempt is made to account for the wave characteristics of radiant energy.

Explanation of Visibility

Many attempts have been made to explain how objects can be seen. Aristotle, an early Greek scientist, believed that light was sent out from the eye. When it fell upon the object, the object could be seen. He never thought to explain why you couldn't see in the dark.

For many centuries, Aristotle's explanation of visibility was believed to be correct. But about 1670, Sir Isaac Newton,

Details in the interior of the cave, below, cannot be seen because no light source illuminates them.

Hawaii Visitors Bureau

an English scientist, developed an entirely different theory of visibility. He suggested that when an object such as a lamp gives off light, light floods all the space around the lamp. Some of this light falls upon objects around the lamp and is ***reflected,*** or returned to the eye. It is the reflected light that makes the object visible.

Scientists today explain visibility in about the same way Sir Isaac Newton explained it. The sun, a lighted electric lamp, and a neon sign are sources of light and can be seen because of the light that comes from them directly to the eye. An object flooded with light from a source of light is said to be ***illuminated.*** Illuminated objects are visible because they reflect light to your eyes.

CONTROL OF LIGHT

Light, as it moves from point to point, can be controlled with mirrors and lenses. This control depends upon reflection and ***refraction.*** Refraction is a change in the direction of light when passing obliquely through substances of different densities.

The explanations that follow assume light to travel as rays. These could be considered as paths of photons moving from the source to the illuminated objects. They derive from a particle model.

Reflections From Mirrors

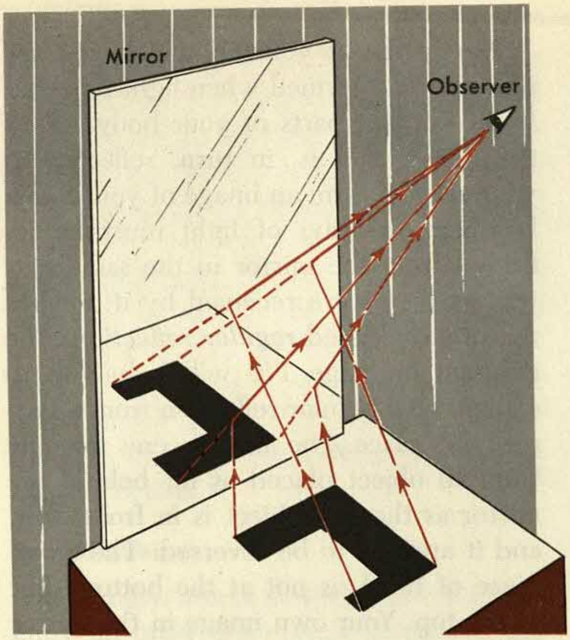
Any smooth surface which reflects light so that an image can be formed is known as a ***mirror.*** A mirror can be made by coating one side of a piece of glass with silver or aluminum. Highly polished metal and a pool of quiet water will also mirror objects on their surfaces.

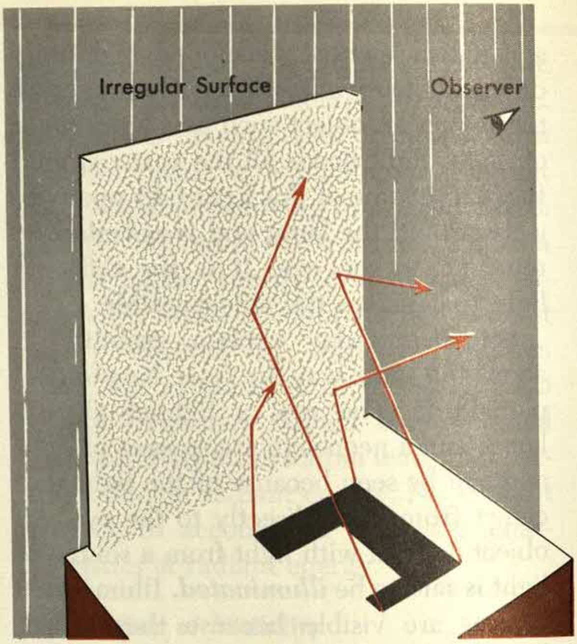
The image of yourself which you see in a mirror is formed when light reflected from different parts of your body strikes the mirror and is, in turn, reflected to your eye. To form an image of your body, however, the rays of light must be reflected from the mirror in the same pattern as they were received by it. Such a reflection is called ***regular reflection.*** The diagram on page 176 will help you to explain how regular reflection from a mirror takes place. The image seems to come from an object placed as far behind the mirror as the real object is in front of it, and it appears to be reversed. The crosspiece of the L is not at the bottom, but at the top. Your own image in the mirror is also reversed (although it is not so easy to realize it) because the mirror has reflected, or changed, the direction in which the light rays are traveling.

Most of the mirrors in use are flat, or plane, mirrors. In such mirrors, the image appears the same size as the object. Some mirrors, however, have surfaces which curve inward, or outward.

If the light strikes a mirror that is curved inward, a ***concave*** mirror, the image is much larger than the object when the object is close to the mirror. Such mirrors are used to enlarge the image of the face for shaving, or for applying cosmetics to the face.

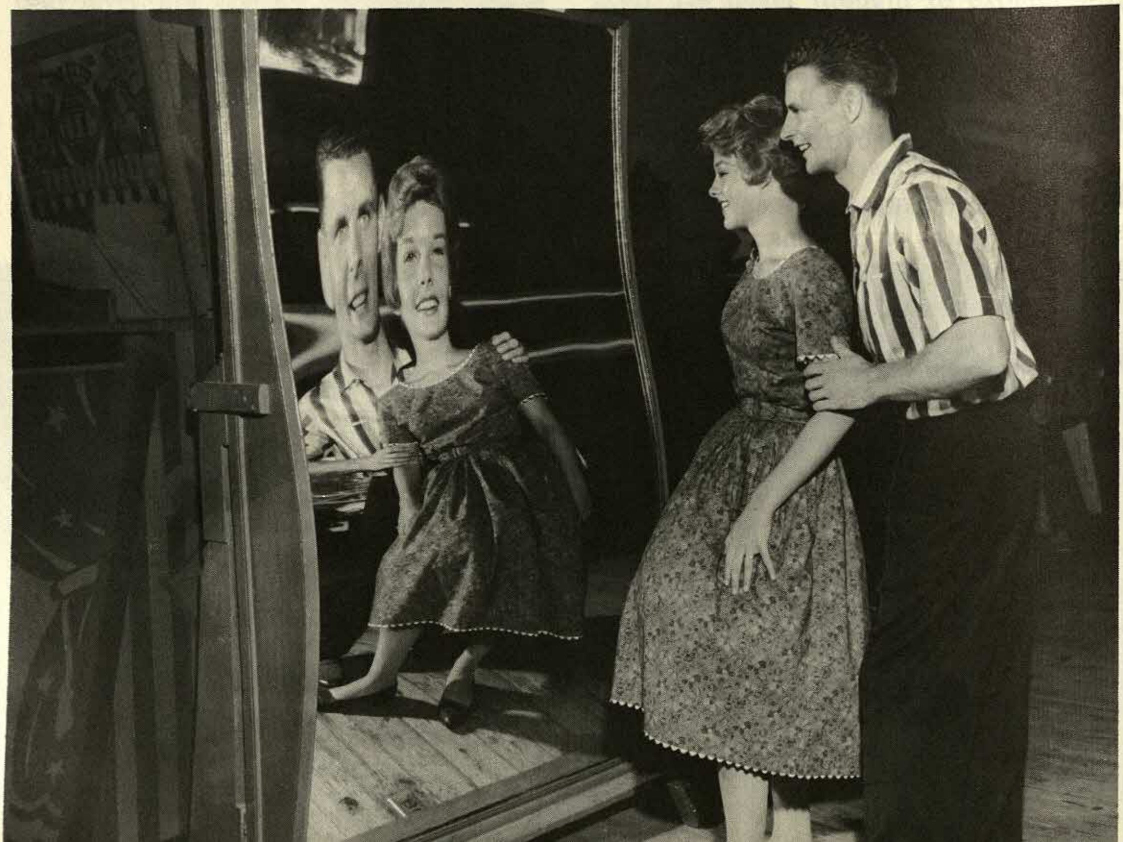
If, on the other hand, light strikes a mirror that curves outward at the center, a ***convex*** mirror, the image formed is smaller than the object. Mirrors of this type are often used on automobiles and trucks because, although the images are smaller than the objects, the driver can see a larger part of the road behind him.





It's all done with a mirror. Top half, being concave, enlarges the image reflected in it. Bottom half of mirror, being convex, makes the boy and the girl appear shorter than they really are.

Riverside Amusement Park—Chicago



Reflections From Uneven Surfaces

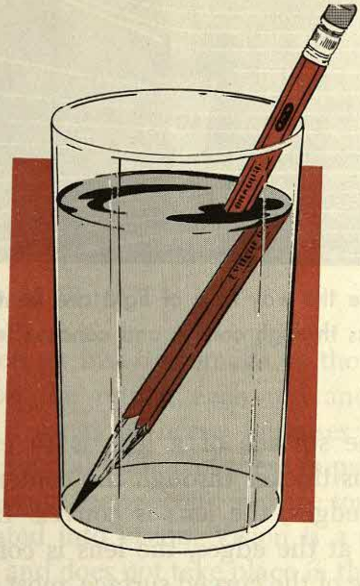
The paper in this book appears to be smooth, but if you examine it under a microscope, you will see that it is quite rough. When rays of light strike such a rough, or uneven, surface, their reflection is said to be ***diffuse.*** The diagram on page 176 will help you to understand why images are not formed by light which is reflected from an uneven surface.

Refraction of Light

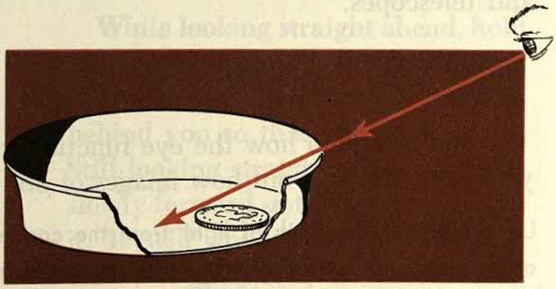
If a pencil is placed in a glass of water, it appears to be broken, as you can see.

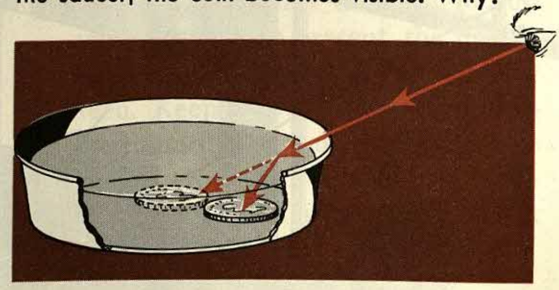
This is explained by the fact that the light rays coming from the pencil are bent as they leave the water because the speed at which they travel is changed. As you know, the speed of light through different substances varies. When a beam of light passes from air to water, it is slowed down. When a beam of light passes from water to air, it travels faster. Such bending of light rays is called refraction.

Place a coin at the bottom of a shallow saucer. Then stand so that you look directly down on the coin. Now kneel down so that you are in a position where the rim of the saucer just hides the coin from sight. While you hold this position, have someone pour water over the coin to cover it. Be sure that the position of the coin is not disturbed by the pouring of the water. What effect does the water have on the coin? Can you now see it? Again stand directly over the coin. Has the water had any effect on the actual position of the coin in the saucer?

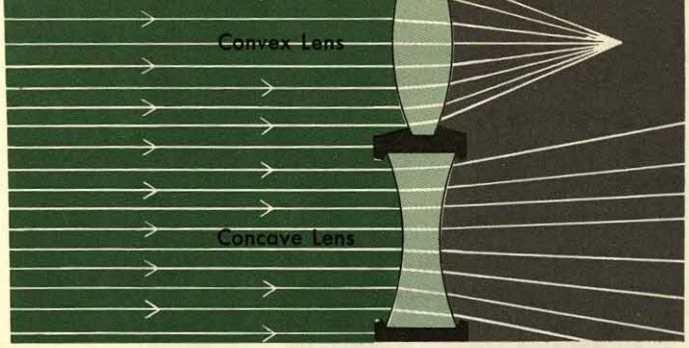


When one part of a pencil is in water and the other part is in air, the pencil appears to be broken. How does refraction explain this?





The coin is not seen by the eye when there is no water in the saucer. When water is put into the saucer, the coin becomes visible. Why?



Compare the way rays of light are bent when they pass through convex and concave lens.

Lenses

If the surface of a lens is so curved that it is thicker through the center than at the edges, the lens is convex. If it is thicker at the edges, the lens is concave. Because of the curved surface, most of the light passing through a lens is refracted, as shown in the diagram on this page. Lenses are used in eyeglasses, field glasses, and telescopes.

THE EYE

To help explain how the eye functions, you must first find out how images of objects can be formed without the aid of mirrors.

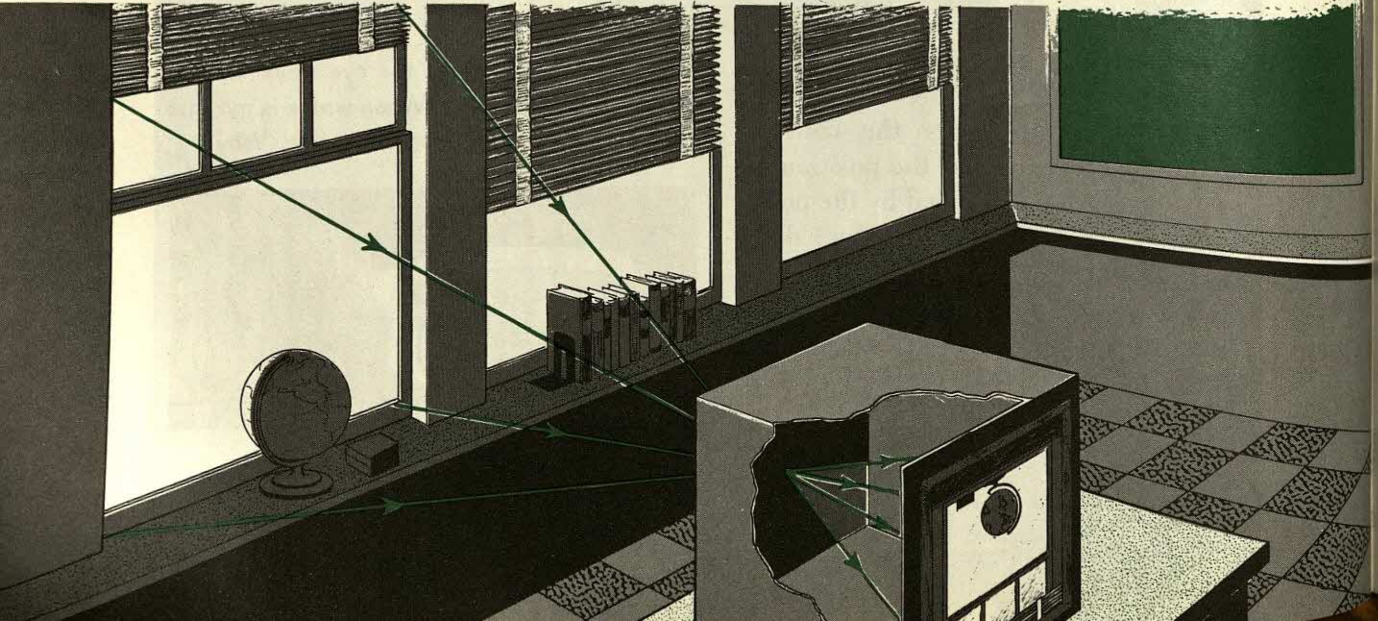
One simple way to produce an image is to use a pinhole camera, shown below. You will note that light rays from the top of the window travel in a straight line through a hole and form an image on the lower part of the screen in the camera. Light rays from the lower part of the window travel through the hole and form an image on the upper part of the screen. The image on the screen is ***inverted.***

If a convex lens is used in place of a pinhole, a much clearer inverted image can be formed. An image that is sharp and clear is said to be ***in focus.*** A convex lens with greater curvature will focus an image closer to the lens than one with less curvature. If the same lens is focused on a near and a distant object, the image of the near object is formed farther from the lens than that of the distant object.

How the Eye Works

In the eye (see diagram facing page 488) the ***retina*** is compared to the screen in the

Lines indicate the path of light from the corners of the window to the image. Light from every other point on the window travels to approximate point in image at back of the pinhole camera.



camera. The distance between the retina and the lens remains the same. Therefore, to bring both near and distant objects into sharp focus on the retina, the curvature of the lens must be changed.

When the eyes are focused on a near object, tiny muscles cause the lens to become more convex. It is held in this position as long as you look at the near object. When eyes are focused on a distant object, muscles allow the lens to become less convex. The process of focusing images on the retina is called ***accommodation.***

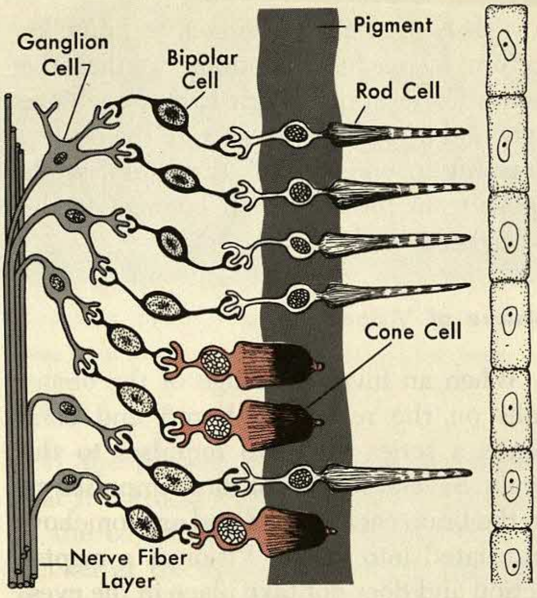
The retina is an extremely complex film covering the greater part of the inside surface of the eyeball. It contains some seven million separate nerve ends, called ***rods*** and ***cones,*** which react to light falling on them. The rods are primarily sensitive to changes in the strength of light, while the cones are primarily sensitive to color. The rods and cones are not evenly distributed throughout the retina. Near the center of the retina, where the image is focused, there are only cones. There are about 34,000 cones in an area only this large ■ (.5 mm. on each side)! Vision, for both color and detail, is best when the image falls on this area, called the ***fovea.*** The rest of the retina has a mixture of rods and cones, with the cones steadily decreasing in number away from the center. Only rods are found at the outer edges of the retina.

There is a separate nerve fiber for each rod and cone near the central part of the retina, but there is only one for groups of nerve endings nearer the edge. As a result of this grouping, some one million, rather than seven million, separate nerve fibers combine to make up the ***optic nerve*** for each eye. The optic nerve branches before it reaches the brain so that the nerve fibers from the left half of each eye (divided up and down through the center) connect to one side of the brain, while those from the right half connect to the other side of the brain.

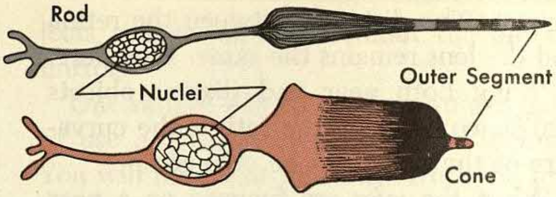
Nature of Vision

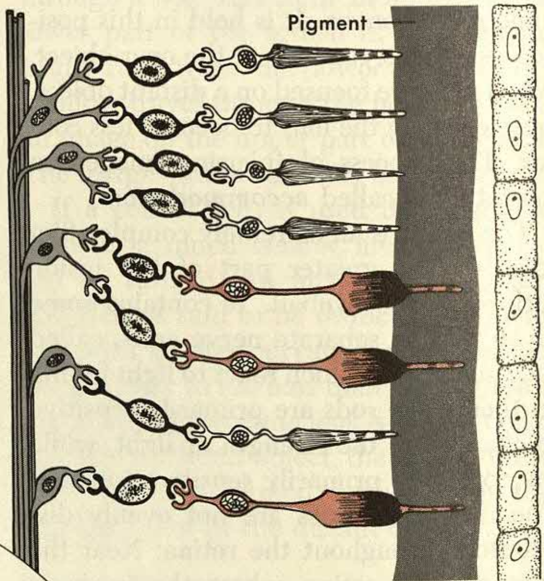
When an inverted image of the object falls on the retina, each rod and cone sends a series of nerve impulses to the brain. Several million of these impulses go to the brain each second and are somehow translated into vision. Vision is a mental action and does not take place in the eyes. For this reason, brain injuries may affect vision even though the eyes themselves are perfect in every respect.

While looking straight ahead, hold some small colored object at arm's length in your hand and far enough behind you so that you can't see it. Still looking straight ahead, bring it slowly forward until you can just see it. It will appear as an indistinct, black, or gray, object. Move it up and down. You can see the movement clearly. Now move the object forward until you can just make out the color. Although you are aware of its color and may be able to tell which colors are present, the details of the object are still not clearly seen. Keep moving the object forward until you can see its details clearly. Not until the object is directly in front of you can you see it in any detail.

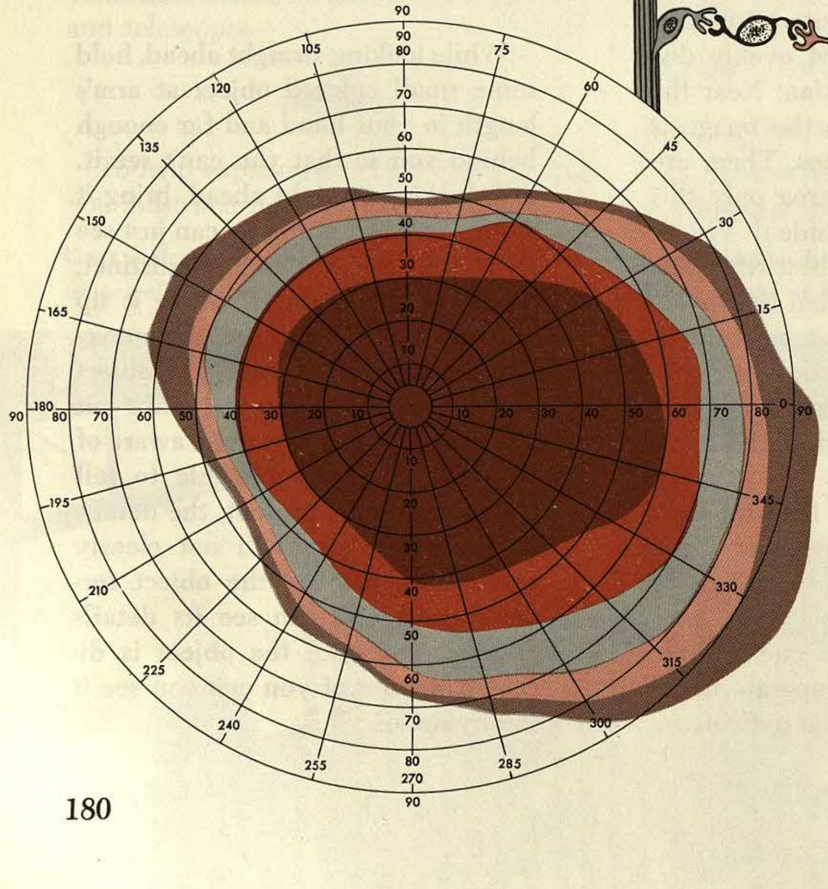


Mechanical changes occur in the retina during light and dark adaptation. In light adaptation, the pigment expands and the cones retract.





In dark adaptation of retina, cones extend to rods, which retract slightly. Pigment moves to posterior position.



Perimeter chart of the right eye shows the field of vision for yellow, blue, red, and green. In color vision, the eye is most limited for green. Blue and yellow vision covers more extended eye area.

An explanation of these characteristics of vision can be found in the make-up of the eye. The image of an object just inside the field of vision falls near the outer edge of the retina. Because there are rods and relatively few nerves from them in that area, objects are indistinct and have no color. However, their movement is readily seen because movement of the object changes the strength of the light falling on the rods. As the object is moved toward the center of the field of vision, its image moves toward the center of the retina. Now it falls on some cones and you become aware of the color, as well as greater detail, since the nerve fibers are more numerous in this part of the eye. Finally, the image falls on the tiny area packed with cones, and the object with all its colors is seen in detail.

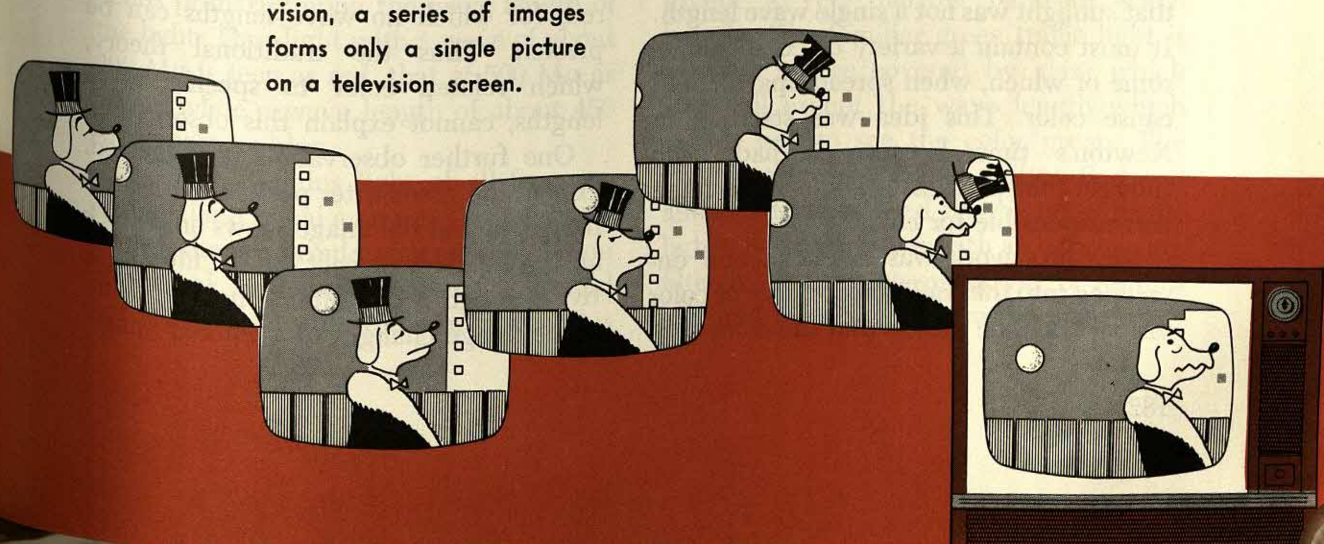
Persistence of Vision

When an image is removed from the retina suddenly, its effect does not stop instantly. In other words, some effect seems to remain, or ***persist,*** after the image is gone. If wave lengths of light that cause red, blue, and green are presented to the eye in order and at a sufficiently rapid rate, such as thirty times per second, the cones are still sending "see red" impulses to the brain when blue arrives. They then send both "see red" and "see blue." Before these stop, green comes along so that they send all three at the same time. As a result, you see white. This action of the eye in blending individual images together is known as ***persistence of vision.***

The retina also shows persistence of vision for black and white images. The movement seen in both motion pictures and on television screens is caused by this behavior of the eye. In both cases, individual still pictures, each a little different from the one ahead of it, are presented at a rapid rate. The eye blends the individual images together, and you see continuous smooth movement rather than a series of still pictures.

COLOR VISION

Most people see the world in color. A light source seemingly without color illuminates objects which are then seen in a multitude of hues. Can you explain how this is possible?



Because of persistence of vision, a series of images forms only a single picture on a television screen.

Color vision has been studied by scientists for many years. Out of such study certain ideas have emerged. First, color results from the response of a person to the stimulation of his eyes by light energy. Color is, therefore, seen in the mind rather than in the eyes. Second, seeing color in response to light coming directly from its source may be a different process from that of seeing color in response to light reflected from objects in the environment.

The second idea is relatively new. For many years, it was thought that there was no difference in the way you respond to direct light and to light reflected from illuminated objects. A theory of color vision, old and widely accepted, was based upon this assumption.

In 1959, Dr. E. H. Land, an American scientist, proposed a modification of the traditional theory. He suggested that you do not see color in the environment in the same way that you see color from spots of light. His theory is called the ***Land theory of environmental color.***

Traditional Theory of Color Vision

Sir Isaac Newton studied color. He used sunlight and a prism to arrive at the observations diagrammed on page 186. From these observations he concluded that sunlight was not a single wave length. It must contain a variety of components, some of which, when spread apart, could cause color. This idea was startling in Newton's time because it had been thought that the glass prism, not the light, was responsible for color.

Newton's work was extended and developed into the traditional theory of color vision. Its basic idea is that the color seen is related to the frequency or frequencies of light striking the eye. The order of colors from red to violet follows the wave length as shown in Figure E, page 186. It was found that most of the colors, including white, could be produced by mixing wave lengths for red, blue, and green in the proper proportion, as shown in Figure A on page 186. From these experiments, it was assumed that the color seen depended not only upon which wave lengths reached the eye, but in what proportion.

Land Theory of Environmental Color

According to Dr. Land, the inadequacy of the traditional theory of color vision is shown by the demonstration described below.

First, two separate frequencies that produce yellow are projected onto a screen. The screen looks yellow, as the traditional theory suggests. Next, two photographic positives of some colored objects are made from ordinary black and white film. One is from an exposure through a red filter, the other through a green filter. Finally, using the same wave lengths in yellow, the positives are projected as a single image on the screen. Are the objects all yellow? No! They are seen in a wide range of color. One sees colors such as blue and red, for which no wave lengths can be present. Thus the traditional theory, which related color to specific wave lengths, cannot explain this observation.

One further observation is suggested. Project the green filter positive with ordinary light and the image shows only black and white. Now project the red filter positive through a red filter. The black and white image changes to a colored image!

On the basis of these and other experiments he has performed, Dr. Land suggests a different theory for seeing colored objects. See photographs, page 187.

In viewing our sunlit world, the eye and mind establish a balance point between the low and high frequencies of light. Neither the actual value of the wave length, nor the overall brightness of each long and of each short wave length, is as important as the random spreading of the wave lengths from point to point in the scene. Thus, it appears that the colors in a natural image may arise from the interplay of long and short wave lengths rather than from any definite wave lengths, as suggested by the older theory.

Color of Light Sources

The sodium-vapor lamps used to light streets and highways appear yellowish in color. When light from a neon sign strikes the eye, color is seen. In both of these cases, the range of wave lengths of the light seen was severely limited as compared to sunlight. These examples, plus many others, indicate that when direct light, having a limited range of frequencies, strikes the cones of the eye, the nerve sensations sent to the brain are such that a color is seen. The exact color depends primarily upon the wave length of the light. Thus light with a wave of about 600 Mμ is seen as red, that of 500 Mμ as green, while a wave length of about 450 Mμ is seen as blue.

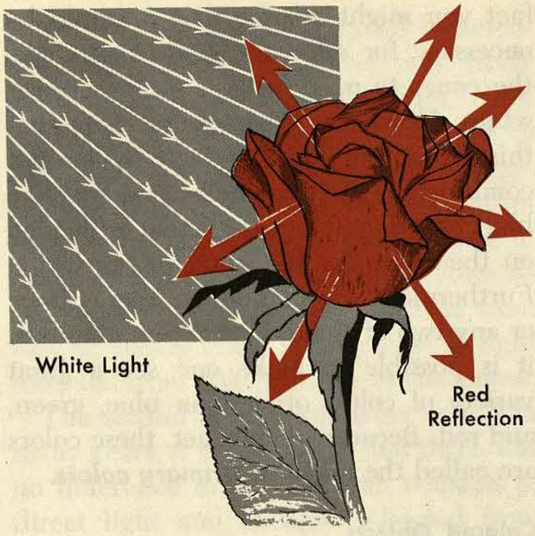
Sunlight contains light of all frequencies in about equal amounts. Therefore its source, the sun, would appear white if you could look at it directly. But you should not look directly at the sun. From this fact you might assume that it would be necessary for all wave lengths to strike the cones to make a light source appear white. However, experiments show that this is not the case. In fact, the proper combination of frequencies that produce blue, green, and red is all that is needed on the cones for the mind to see white. Furthermore, by combining these three, or any two of them, in different amounts, it is possible to make one see a great variety of colors other than blue, green, and red. Because of this fact, these colors are called the ***additive primary colors.***

Colored Objects

The explanations which follow are based upon the traditional theory of color vision. As you study them, see what modifications would be necessary if they were based on the Land theory.

Light sources which produce light of a limited frequency range are seen as colored. Neon lamps, sodium-vapor street lamps, pastel fluorescent lamps, and ore seen under "black light" (ultraviolet) are examples of this type.

Light sources are often made to appear colored, even though they are not. This is accomplished by allowing the light to pass through some material that stops all except a very narrow band of wave lengths. The familiar green traffic light is a white source covered by glass which stops all except the wave length which causes you to see the color green. The glass is, therefore, called a ***filter.*** Red and amber filters are used for the other traffic lights. A white source with an appropriate filter is the most common way of obtaining light of only certain wave lengths.



Red rose absorbs red and reflects other colors.

If an object appears red when illuminated by the sun, it will appear red only when, or where, red-producing wave lengths fall on it. It will appear brown or black when illuminated by light lacking the red-producing wave lengths. This suggests that the color of an object seen by reflected light (red, brown, and black in this case) depends upon the wave lengths it selects from the light striking it, which is to be reflected to the eye. Note that the color depends upon two factors: first, the wave lengths present in the illuminating light and, second, the wave lengths reflected to the eye. A navy blue suit or dress appears to be blue in daylight because it reflects to the eyes those wave lengths which cause you to see the color blue. The same suit or dress appears to be black when seen in artificial light, which is weak in the blue-producing wave lengths. That is why colored cloth is matched with other cloth, or thread, in daylight rather than in artificial light.

Illumination for Good Vision

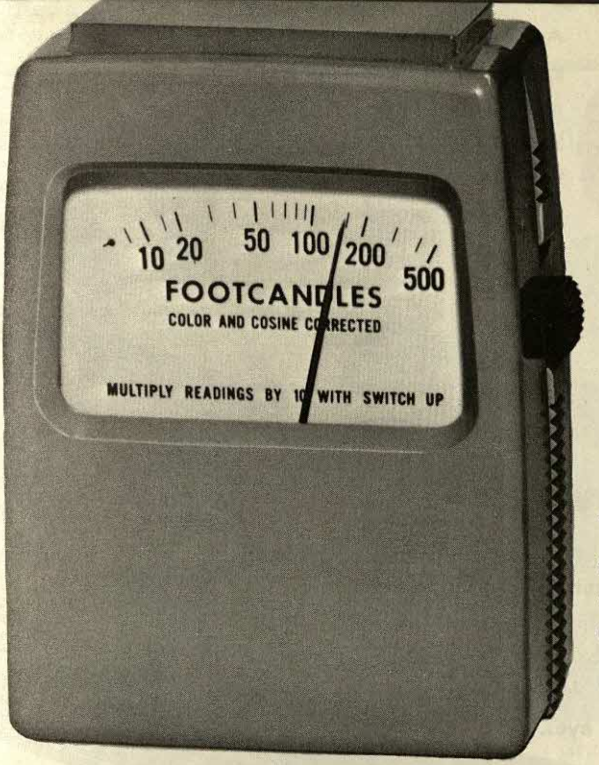
Good vision depends not only upon the proper functioning of the eye, but also upon the kind and amount of illumination. Of course, if the eye is not functioning properly, vision is impaired.

Not all light contains the same amount of the various color-producing frequencies. The light from three different sources has been analyzed, and the results are shown in the graph on page 185. Thus it is quite clear that an object might appear to be a different color in light from each of these sources. Vision would be most complete, and thus best, in light with a frequency-content most nearly equal to that of sunlight.

Illumination must be sufficient for good vision. The unit most commonly used for measuring illumination is the ***foot-candle.*** Does the name of this unit tell you how it was derived? A foot-candle meter is placed on a surface whose illumination is being measured. The intensity of illumination in foot-candles is then indicated on the dial. When the sun is highest, it illuminates a surface with about 9,600 foot-candles.

The illumination of a surface decreases rapidly as the distance from the light source increases. If you study the diagram on page 141, you will understand why this is so. In choosing a place to read, do not sit too far from the source of light.

For good vision, the contrast between the illumination of your work and that of your surroundings should not be too great. If your work is brightly lighted and the rest of the room is dark, each time you look away from your work the muscles of your eyes must open or close the pupils


10
20
50
100
200
500
FOOTCANDLES
COLOR AND COSINE CORRECTED
MULTIPLY READINGS BY 10 WITH SWITCH UP

With a foot-candle meter such as this one, the amount of illumination in a room can be measured accurately.

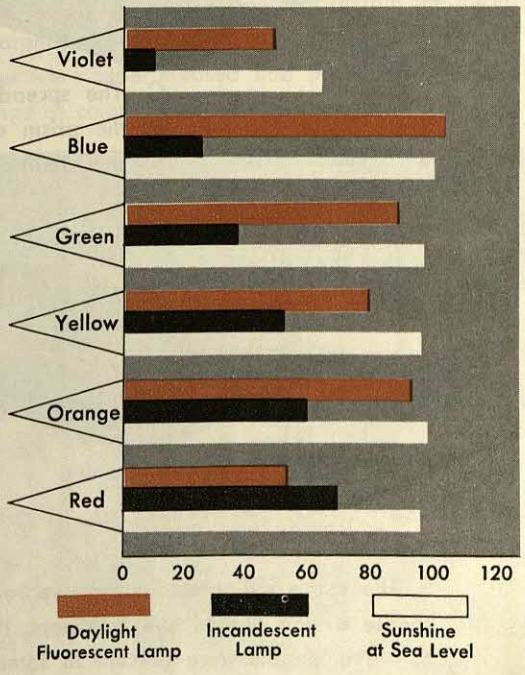
General Electric Corp., Inc.

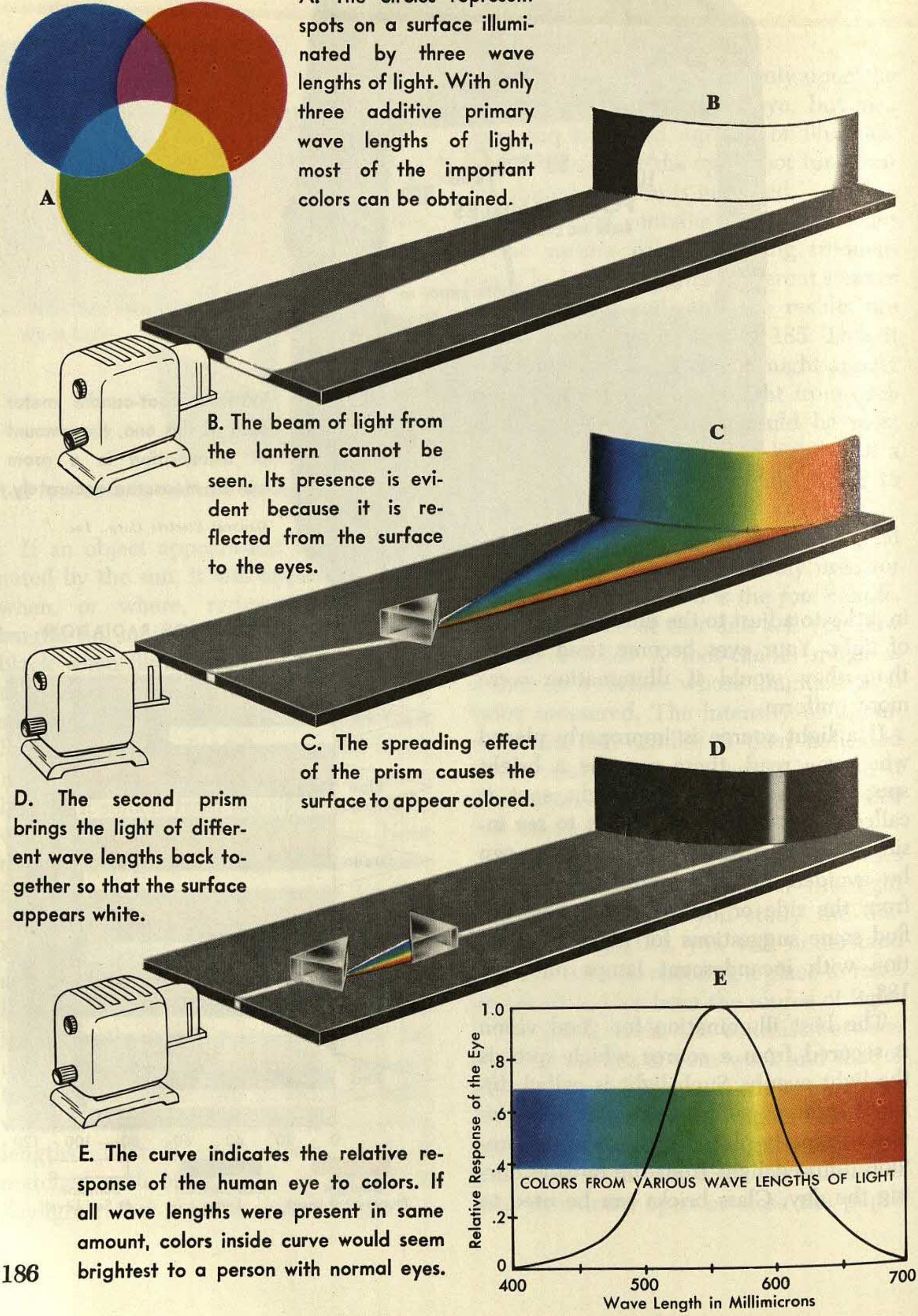
in order to adjust to the different amounts of light. Your eyes become tired sooner than they would if illumination were more uniform.

If a light source is improperly placed when you read, there may be a bright spot on the paper. The bright spot is called ***glare***. It is very difficult to see inside the area covered by glare. Glare can be avoided by illuminating your work from the side or from behind. You will find some suggestions for good illumination with incandescent lamps on page 188.

The best illumination for good vision is secured from a source which spreads the light evenly. Such light is called ***diffused*** light. A sufficient number of windows properly placed in a room will provide diffused light from the outside during the day. Glass bricks can be used to

RELATIVE STRENGTH OF RADIATION





A. The circles represent spots on a surface illuminated by three wave lengths of light. With only three additive primary wave lengths of light, most of the important colors can be obtained.

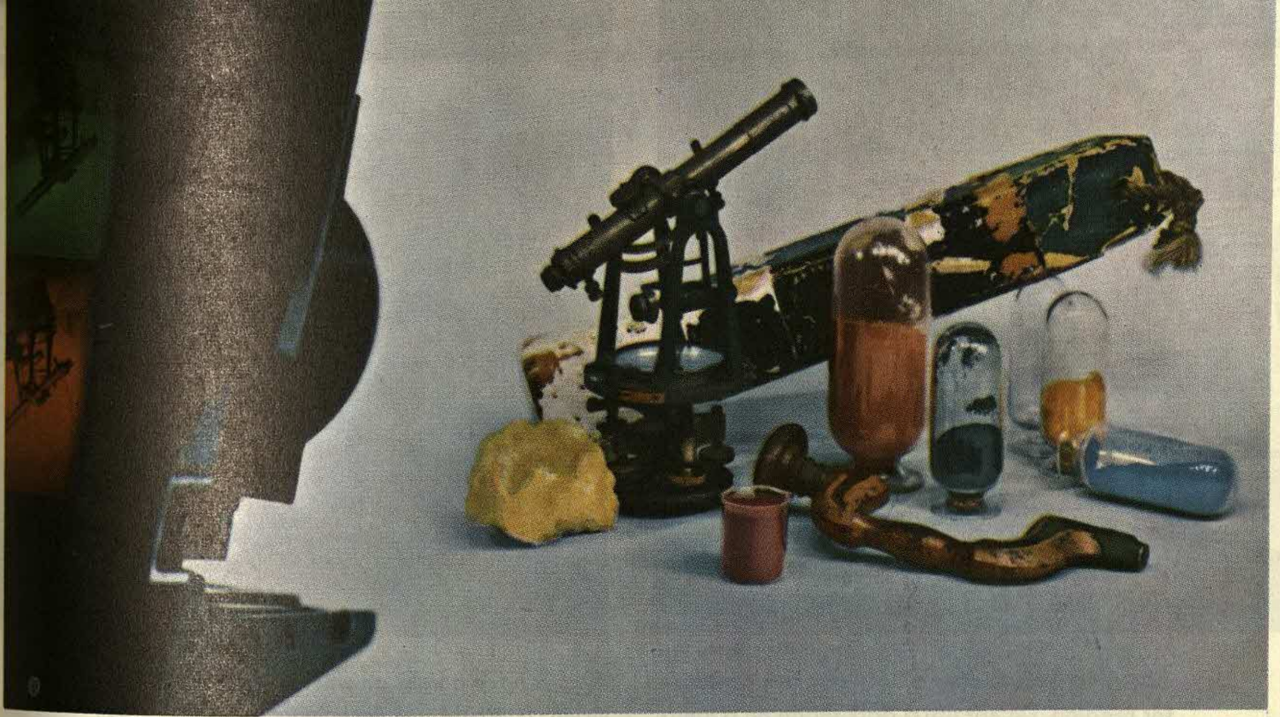
B. The beam of light from the lantern cannot be seen. Its presence is evident because it is reflected from the surface to the eyes.

C. The spreading effect of the prism causes the surface to appear colored.

D. The second prism brings the light of different wave lengths back together so that the surface appears white.

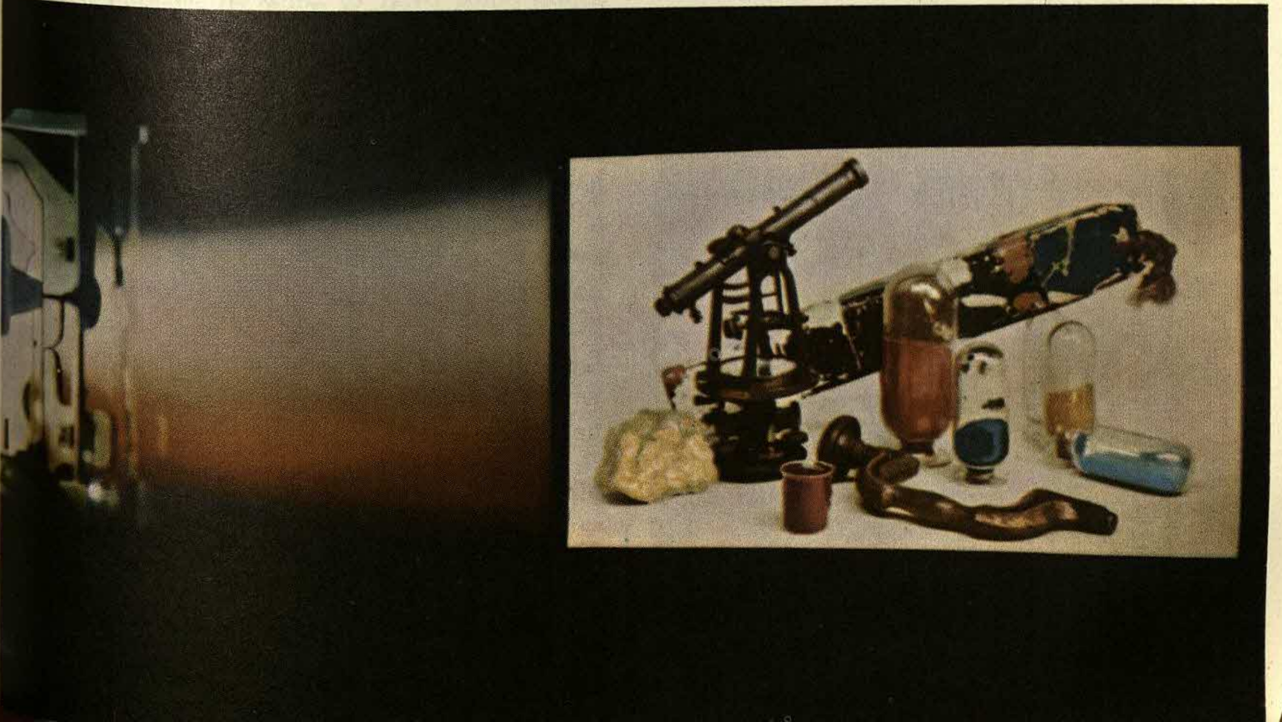
E
1.0
.8
.6
.4
.2
0
Relative Response of the Eye
COLORS FROM VARIOUS WAVE LENGTHS OF LIGHT
400
500
600
700
Wave Length in Millimicrons

E. The curve indicates the relative response of the human eye to colors. If all wave lengths were present in same amount, colors inside curve would seem brightest to a person with normal eyes.



William Vandivert (Scientific American)

Colored objects in top picture were photographed on black and white film by dual camera at left. Uncovering of ground-glass screens shows that one image was photographed through a green filter and the other through a red one. Black and white transparencies were then made from the negatives. In the bottom photograph, the "red" transparency was projected through a red filter, and the "green" one without a filter. When the images were superimposed and projected onto the screen at right, a picture of the objects in a full range of color appeared there.



General Electric Corp., Inc.

About forty foot-candles of light are desirable for reading. Do not use a dark shade on a lamp.

General Electric Corp., Inc.

Always have a light on when viewing night television. It should not form reflections on screen.

admit additional light. Artificial lights should be arranged so that the light is spread throughout the room. Light colors on walls and ceilings diffuse light throughout the room. The light-reflecting values of the most commonly used colors are shown below.

Color and Safety

Proper use of color helps prevent accidents. Industrial plants can be made safer by wise use of color, even though a foot-candle meter shows that there is adequate illumination. In such plants, red can be used to warn of danger and fire hazards. Orange or yellow, easily visible, can be used to attract attention to overhead moving equipment so that workmen will see it as they move about. Traffic lanes can be gray, bordered with orange or red, to set them apart from the rest of the floor. Walls that are painted in soft colors do not distract attention from the work, yet they help diffuse light throughout the room.

Color can also be used to make homes safer. Floors in dimly lighted parts of the home should be painted a light color. The bottom step of a stairway, or of a poorly lighted entrance, stands out if painted white. Basement electric switches, furnace-door handles, and fire extinguishers stand out if they are painted a bright red. You can recognize them quickly then.

Light-Reflection Values

	Percent
Light—almost white	85
Cream	70–75
Yellow	55–65
Green	35–50
Blue	10–50

The Eye and Good Vision

Even though illumination is adequate, many people do not have good vision because of defects in the structure of their eyes. The most common defects are ***nearsightedness, farsightedness,*** and ***astigmatism.*** Diagrams facing page 488 show you how the shape of the eyeballs causes the first two of these defects. When the cornea of the eye is uneven, vision is blurred and the person is said to have astigmatism. This can be corrected by special lenses.

Care of the Eyes

Good vision is so important in successful living that you should take proper care of your eyes. Here are some helpful suggestions.

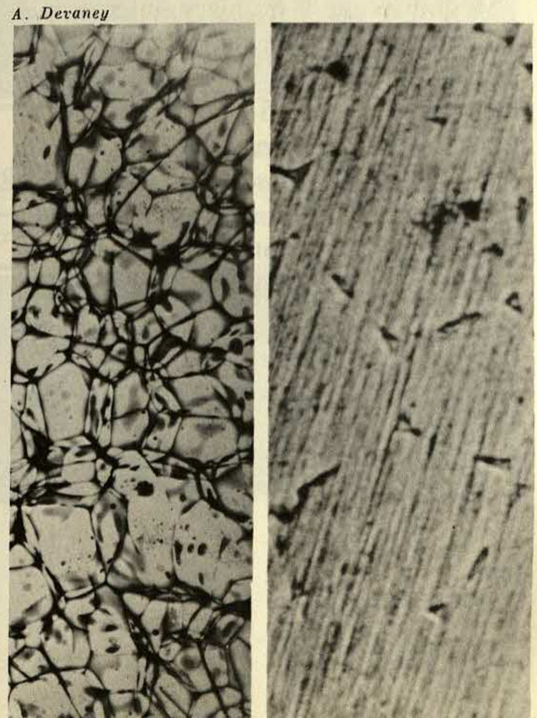
1. If you get headaches when reading or studying, or if you do not see the writing on the blackboard clearly, have your eyes examined.
2. Provide proper illumination for good vision. This means a sufficient amount of good light, with a minimum of glare and contrasts. Be sure to have some lamps lighted in the room when you watch television at night.
3. When you are doing close work, look away from your work occasionally to give your eyes a chance to rest.
4. Use extreme care in removing a foreign object from the eye.
5. Take special precautions when you are engaged in activities where the eyes may be damaged easily.

INSTRUMENTS TO AID VISION

When man first realized that there might be many objects in his environment that were either too small or too far away to be seen with the unaided eye, he became curious about them. As a result of this curiosity, he developed instruments to aid him in seeing the "unseen." Instruments that produce enlarged images of tiny objects are called ***magnifiers*** if they are simply constructed, and ***microscopes*** if they are more complicated.

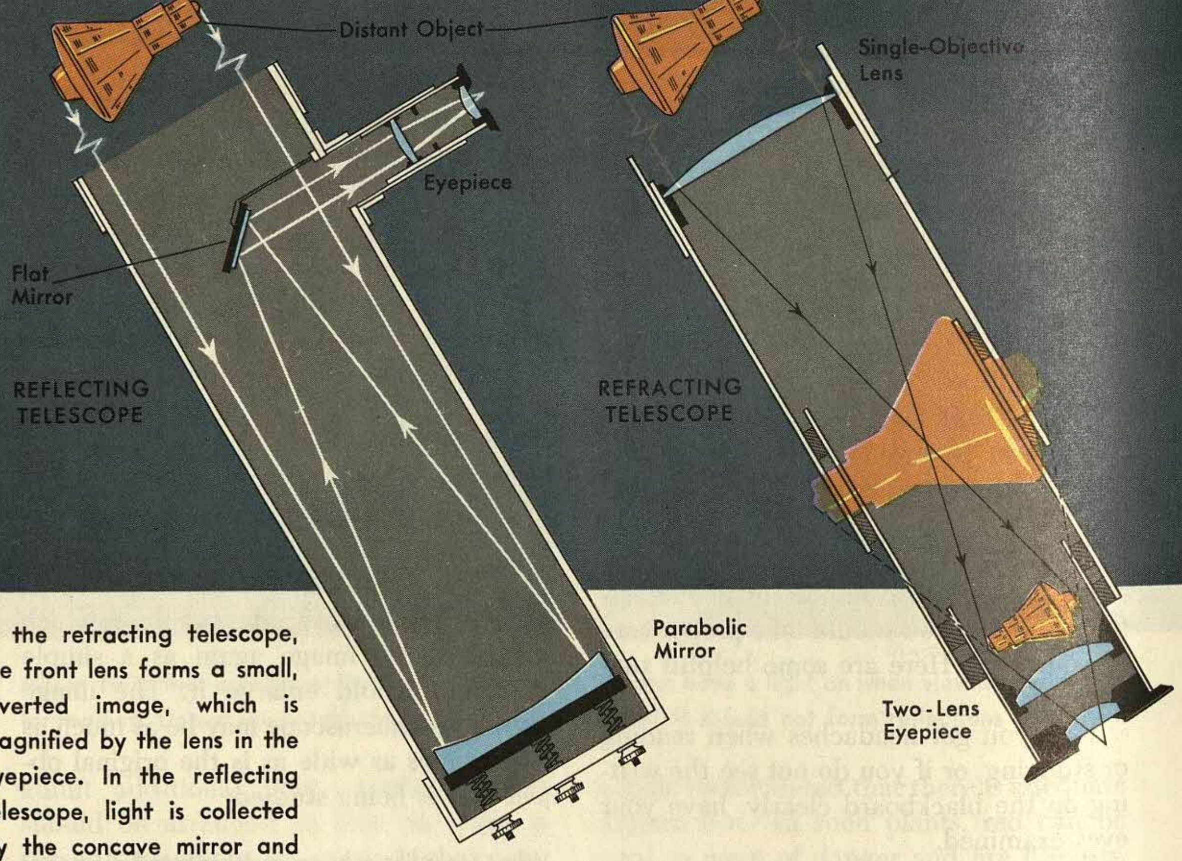
Microscope

A microscope is a double magnifier. The lower, or ***objective,*** lens produces an image inside the microscope, but there is no screen. Instead, this image serves as an object for a lens in the ***eyepiece,*** which magnifies the image again as a simple magnifier would enlarge it. The image seen in the microscope may be as much as 5,000 times as wide as is the original object that is being studied.



What looks like a huge, multi-faceted diamond, left, is actually a tiny portion of aluminum-tin alloy seen under a new x-ray microscope. Light microscope reveals only surface scratches.

A. Devaney



In the refracting telescope, the front lens forms a small, inverted image, which is magnified by the lens in the eyepiece. In the reflecting telescope, light is collected by the concave mirror and reflected by other mirrors into an eyepiece or camera.

Electron Microscope

Magnifiers and ordinary microscopes project images by means of visible light, but some objects are far too small to be observed this way. Such objects can be studied with the ***electron microscope,*** in which electrons are used instead of visible light rays. With this microscope, scientists have been able to photograph the shadows of extremely small objects.

Telescope

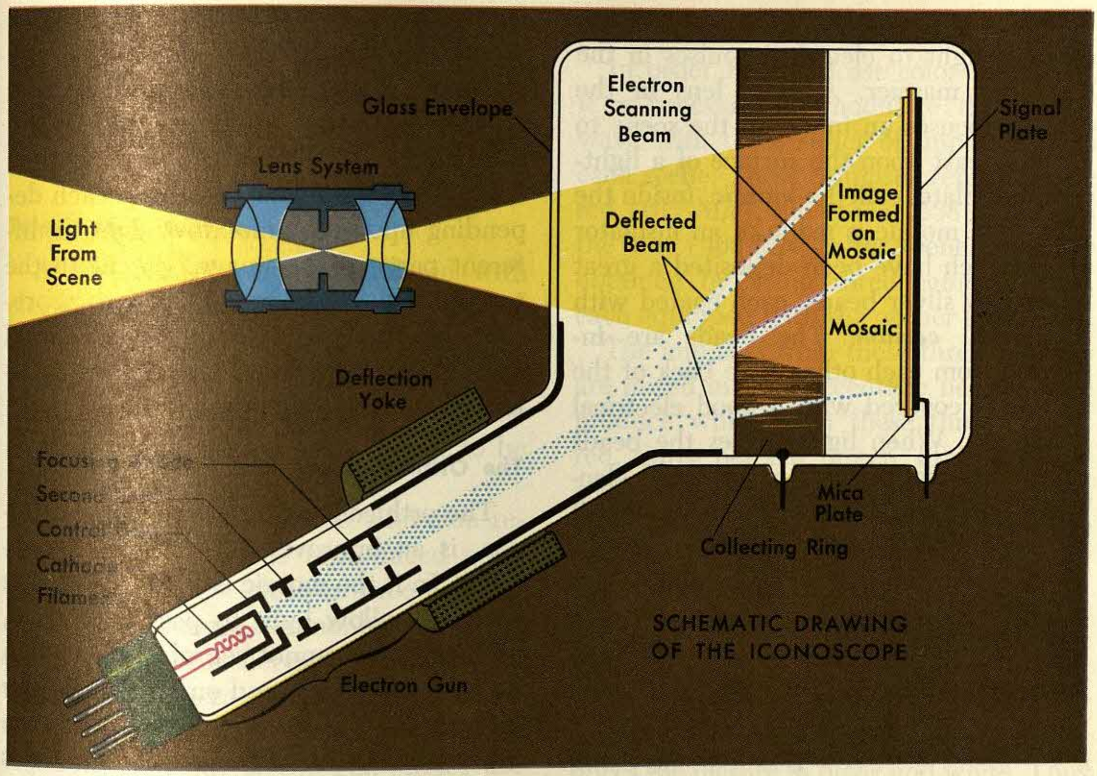
There are two types of telescopes—the ***refracting telescope*** and the ***reflecting telescope***—which are used for observing heavenly bodies.

TELEVISION BROADCASTING

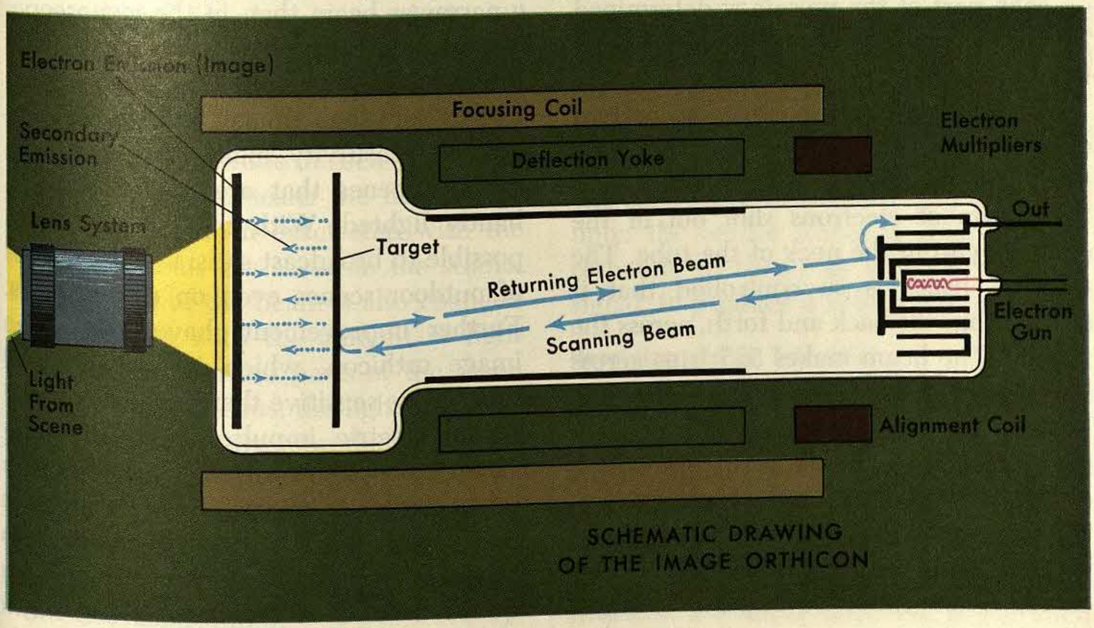
Television broadcasts make it possible actually to see, as well as to hear, events being broadcast. The first step in broadcasting a scene is to change light into electric impulses. This is accomplished by the television camera, which contains an electron tube designed especially for this purpose. Three such tubes used in television cameras are the ***iconoscope,*** the ***orthiconoscope,*** and the ***image orthicon.***

The Iconoscope

The iconoscope is one of the first successful electron tubes used in a television camera. A diagram of an iconoscope is



Schematic drawing of iconoscope, top, and image orthicon, bottom, used in television cameras.



shown on page 191. The iconoscope changes light to electric impulses in the following manner. A glass lens in the camera focuses an image of the scene to be broadcast upon the surface of a light-sensitive plate, called a ***mosaic,*** inside the tube. The mosaic is made of an insulator upon which have been deposited a great many tiny silver beads, each coated with the metal ***cesium.*** The beads are insulated from each other. The back of the mosaic is covered with a good electrical conductor. When light strikes the beads on the mosaic, the cesium gives off electrons. The number of electrons given off by each bead depends upon the amount of light striking it. Those which are brightly lighted give off more electrons than those which are not. As each bead loses electrons, it becomes positively charged. Thus the scene focused on the mosaic has been changed into a pattern of electric charges. The amount of charge on each part of the mosaic is determined by the intensity of light reflected to it from the scene.

The next step is to change the pattern of electric charges on the mosaic into electric impulses. This is accomplished by a thin beam of electrons shot out of the ***electron gun*** in the neck of the tube. The electron beam is so controlled that it ***scans,*** or moves back and forth, across the mosaic. The beam makes 525 trips across the mosaic to scan the image once. The image is scanned by the beam thirty times each second. The beam, as it strikes each of the beads on the mosaic, gives up electrons to replace those driven off the bead by the light forming the image. This causes a small electric impulse to travel from the conductor on the back of the mosaic into the television transmitter. The strength of the impulses depends upon the amount of positive charge the beads obtained when the beam of light struck them. Thus a series of impulses, each depending upon the amount of light in different parts of the image, is sent to the transmitter. These impulses, each representing a tiny part of the image, are used to modulate the radio wave that is transmitted from the television station.

The Orthiconoscope and Image Orthicon

The orthiconoscope, often called orthicon, is an improvement over the iconoscope. In it the mosaic is ***translucent,*** that is, it will allow light to pass through it, although you cannot see objects through it. The scene is focused on one side of the mosaic and the electron beam scans the other side. In the orthicon, the electrons leaving the electron gun are focused into a narrower beam than in the iconoscope. These and other improvements have made the orthicon about ten times more sensitive to light than the iconoscope. This increased sensitivity makes it possible to televise scenes that are much less brilliantly lighted. With the orthicon, it is possible to broadcast satisfactory pictures of outdoor scenes even on cloudy days. Further improvements have led to the image orthicon, which is 100 to 1,000 times more sensitive than the orthicon.

The electric impulses from the television camera are amplified by electron tubes similar to those in a radio and are then used to modulate a carrier wave. The carrier wave of each television station requires a band of frequencies six megacycles wide. The band of frequencies occupied by a station is called a ***channel.*** There are eighty-two channels used by television stations operating in continental United States.

Television Reception

As the carrier wave, modulated with electric impulses produced by the camera, moves past the television receiving antenna, it develops electric impulses in the antenna. These impulses are amplified by electron tubes and cause the image to be reproduced in the receiver.

In most black and white television receivers, the picture is reproduced upon the face of a large electron tube called a ***cathode-ray*** tube (commonly called the picture tube). An electron gun similar to that in the camera tube is located in the neck of the cathode-ray tube. A beam of electrons shot out of the gun strikes the inside surface of the tube. A coating of chemicals called ***phosphors,*** which will produce light when struck by electrons, covers the inside face of the tube. The signals coming from the television station are applied to the tube in such a way that the electron beam scans the face of the cathode-ray tube in exact step with the beam that scans the scene in the studio. The strength of the beam is also changed in accordance with the amount of light reflected from various parts of the scene being broadcast. Thus, the light and dark parts of the scene are reproduced as light and dark parts of the picture on the cathode-ray tube. In this manner, the electron beam in the cathode-ray tube reproduces the scene exactly as it appears in the television studio.

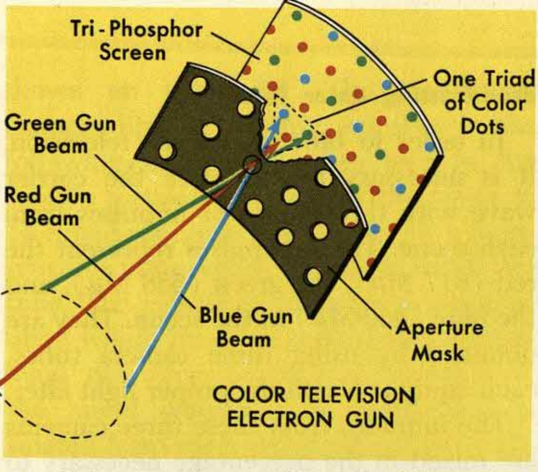
Broadcasting Color Television

In order to broadcast color television, it is necessary to modulate the carrier wave with three series of impulses from each scene. These impulses represent the red (617 Mμ), the green (538 Mμ), and the blue (460 Mμ) in the scene. They are obtained by using three camera tubes, each equipped with the proper light filter.

The impulses from these three cameras are mixed in the percentage necessary to produce white from these three colors: red, thirty percent; green, fifty-nine percent; blue, eleven percent. The result is called the ***Y signal.*** The Y signal takes the place of the signal that would be obtained from an ordinary black and white camera. When an ordinary black and white television receiver is tuned to a color carrier which is modulated with the Y signal, it responds only to the Y signal and reproduces the picture in black and white. Thus black and white receivers will still operate even though the stations are broadcasting for color receivers. The impulses from the color cameras are mixed in other proportions to form two additional signals known as the ***Q*** and ***I signals.*** These are the special color signals which are also impressed upon the carrier wave. A color receiver responds to these, as well as to the Y signal, to produce a color picture.

Receiving Color Television

The heart of a color television receiver is the color picture tube. It is also a cathode-ray tube. The viewing surface is covered with tiny dots of three different phosphors—one that glows red, one that glows green, and one that glows blue when struck by a beam of electrons. In one such



An electron gun in a modern color TV receiver.

twenty-one-inch tube, there are 900,000 dots arranged in groups of three.

In the neck of the tube there are three electron guns, one for each color. Between the guns and the viewing surface, but very close to the latter, a thin sheet of metal containing a tiny hole for each group of three dots (300,000 holes in this case) is carefully positioned. The electron beams from the three guns are made to cross each other at the holes in the plate. Since they come from slightly different angles, they spread apart just enough after passing through the plate for the beam from each color gun to strike the corresponding color dot. See diagram above.

The Q and I signals contained in a wave coming from the transmitter are separated by the television receiver into three separate signals corresponding to those produced by the red, green, and blue cameras in the studio. These separate signals, plus the Y signal, are fed to the three guns in the receiving tube. The beams from the guns scan the tube face as in the black and white receiver. As they scan the tube, each dot glows red, green, or blue, to correspond to those colors present in the studio scene. Thirty complete pictures are formed each second. Because of persistence of vision, the eyes fuse the separate images into a reproduction for both the motion and the color in the studio scene.

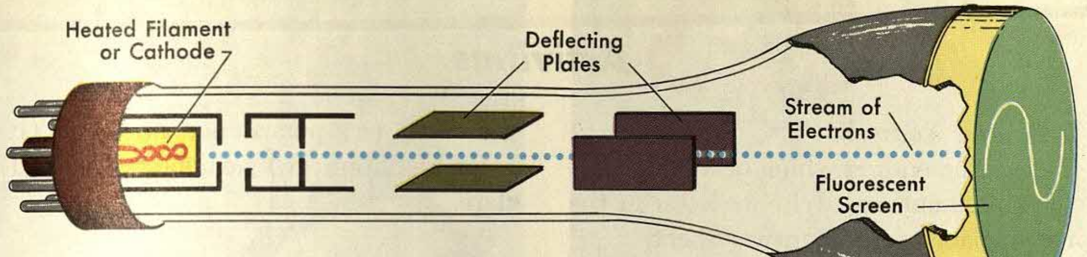
SUMMARY

According to the Bohr-Stoner atom model, light, as radiant energy, is produced by the movement of electrons in excited atoms. Atoms may be excited by adding energy to the atoms with heat, electric discharges, or radiant energy. An object can be seen only if light from some source strikes it and is reflected to the eye, or if the object is the source of light.

Light rays travel in straight lines. They are reflected by certain materials which they strike and are bent or refracted by other materials through which they may pass. Mirrors and lenses are used in reflecting and refracting light in order to control it for improving and extending human vision.

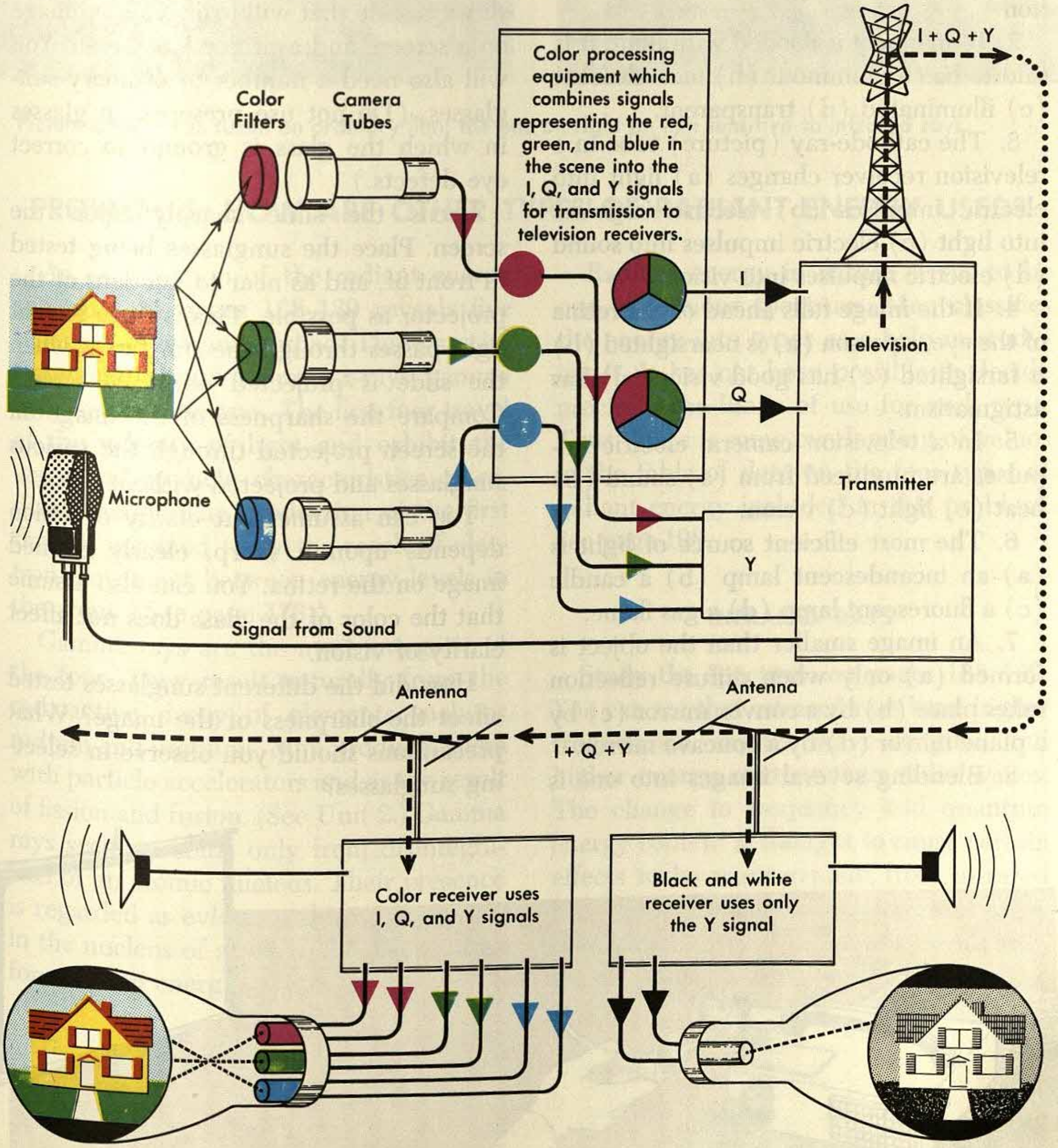
The human eye is constructed so that light can be controlled to produce images to make vision possible. When the eye cannot produce clear images, the difficulties can often be corrected by the use of special lenses. Vision can also be aided by the selection of the proper colors for decorating the interiors of buildings and by controlling the intensity of light indoors so that objects stand out distinctly.

In television broadcasting, light is converted into electric impulses which are used to modulate radio waves. Television receiving stations use the modulated radio wave to change electric impulses into light and thus reproduce the images broadcast.



SCHEMATIC DRAWING OF CATHODE RAY TUBE

Simplified drawing of a cathode ray tube, used in a television receiver. As stream of electrons leaves cathode, it is deflected by electromagnetic coils of deflecting plates. Application of oscillating current causes the electron stream to move up and down and to the left and right.



Activities

A. Testing Yourself

Select the ending which best completes each statement and write its letter in the proper place on your answer sheet.

1. The action which takes place when light from some source strikes an object and then travels from the object to the eyes is known as (a) refraction (b) reflection (c) illumination (d) magnification.

2. If an object is flooded with light, it is said to be (a) luminous (b) incandescent (c) illuminated (d) transparent.

3. The cathode-ray (picture) tube in a television receiver changes (a) light into electric impulses (b) electric impulses into light (c) electric impulses into sound (d) electric impulses into vision.

4. If the image falls ahead of the retina of the eye, a person (a) is nearsighted (b) is farsighted (c) has good vision (d) has astigmatism.

5. In a television camera, electric impulses are produced from (a) sound (b) heat (c) light (d) vision.

6. The most efficient source of light is (a) an incandescent lamp (b) a candle (c) a fluorescent lamp (d) a gas flame.

7. An image smaller than the object is formed (a) only when diffuse reflection takes place (b) by a convex mirror (c) by a plane mirror (d) by a concave mirror.

8. Blending several images into one is known as (a) persistence of vision (b) accommodation (c) nearsightedness (d) glare.

B. Conducting an Experiment

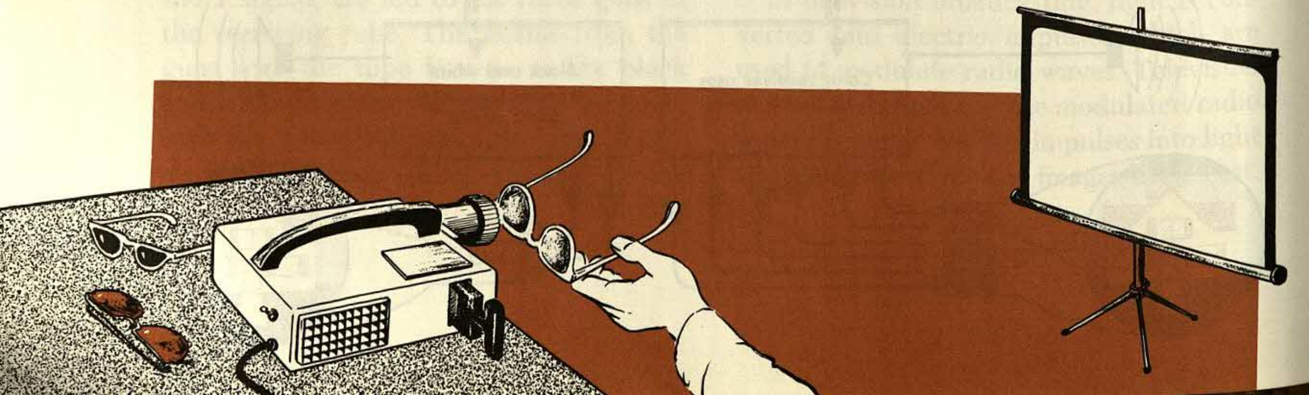
The following experiment will help you solve the problem, "Do sunglasses affect clarity of vision?"

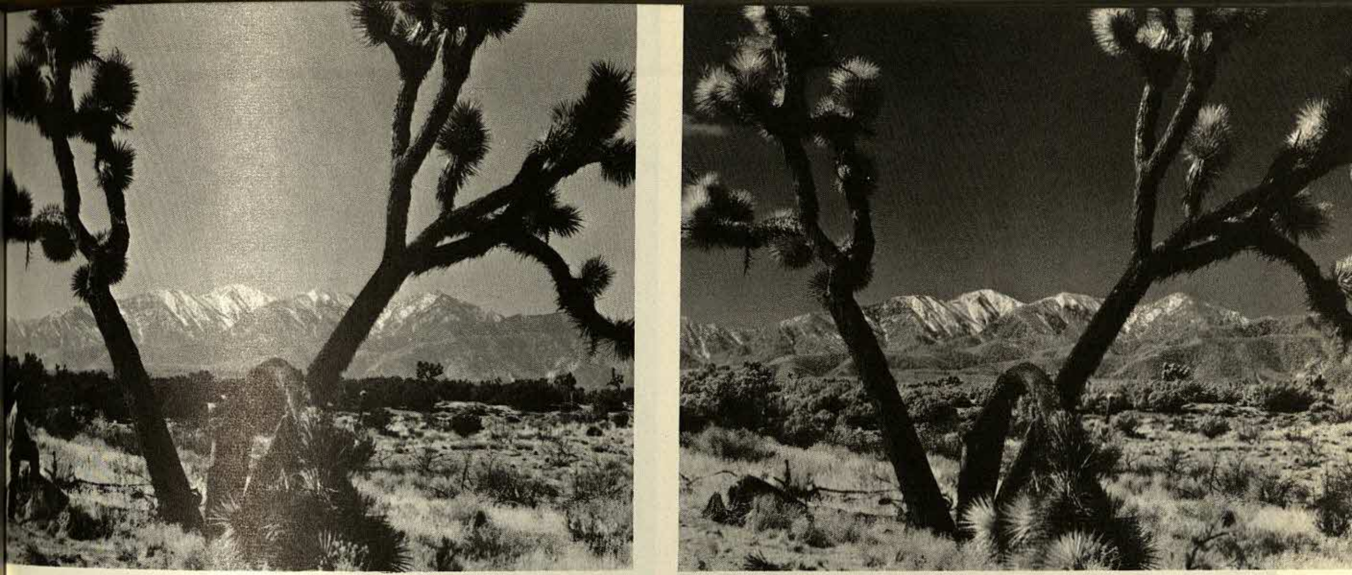
You will need a lantern for projecting slides, a slide that will form a sharp image on a screen, and a projection screen. You will also need a number of ordinary sunglasses. (Do not use prescription glasses in which the glass is ground to correct eye defects.)

Focus the slide sharply upon the screen. Place the sunglasses being tested in front of, and as near to, the lens of the projector as possible. This is done so that light passes through the sunglasses when the slide is projected onto the screen. Compare the sharpness of the image on the screen projected through the various sunglasses and projected without them.

You can assume that clarity of vision depends upon a sharp, clearly defined image on the retina. You can also assume that the color of the glass does not affect clarity of vision.

How did the different sunglasses tested affect the sharpness of the image? What precautions should you observe in selecting sunglasses?





Picture on left was taken on ordinary film; the one on right on film sensitive to infrared rays.

PROBLEM 5: HOW ARE OTHER TYPES OF RADIANT ENERGY USED?

An examination of the radiant energy spectrum on pages 138–139 reveals five types you have not studied. These are infrared and ultraviolet rays, x-rays, gamma rays, and cosmic rays. The first four travel at the velocity of light and exhibit the wave and particle characteristics of radiant energy. The production of the first three is assumed to be the result of electron movement between energy levels in the atom. (See page 173.)

Gamma rays are the most energetic of the four. They result naturally from the radioactive decay of elements such as radium and uranium. Man produces them with particle accelerators and as the result of fission and fusion. (See Unit 2.) Gamma rays seem to come only from disintegration of an atomic nucleus. Their presence is regarded as evidence that some matter in the nucleus of an atom has been transformed into energy.

Radiant energy in nature seems to be one continuous spectrum. Man classifies the energy into types as a help in studying it. It has not been possible to decide precisely the limits of use for each type. Thus, there is some overlapping of values in the table of data on the four types of radiant energy included in this problem. See page 198.

INFRARED RAYS

Study the spectrum on pages 138–139. You can see that infrared rays have higher frequencies, shorter wave lengths, and higher energy content than radio waves. The change in frequency and quantum energy content is thought to cause certain effects to be more evident from infrared rays than from radio waves. Probably their most important effect, so far as man is concerned, is their ability to produce

Standard Oil Co. (N. J.)

heat in any object that absorbs them. The infrared rays from the sun are what make you feel warm when you stand in sunlight. The warmth of an open fire also results largely from these rays.

It is the particle characteristic of infrared rays that seems to be most prominent in determining their heating effect. As they penetrate the surface of a material, the energy of their quanta is transferred to the atoms and molecules of the material. As these become more energetic, they move about more violently. The awareness of such increased molecular activity is spoken of as warmth or, more precisely, as temperature. Because of their penetrating and heating ability, infrared rays are quite often used in the treatment of bruises and sprains.

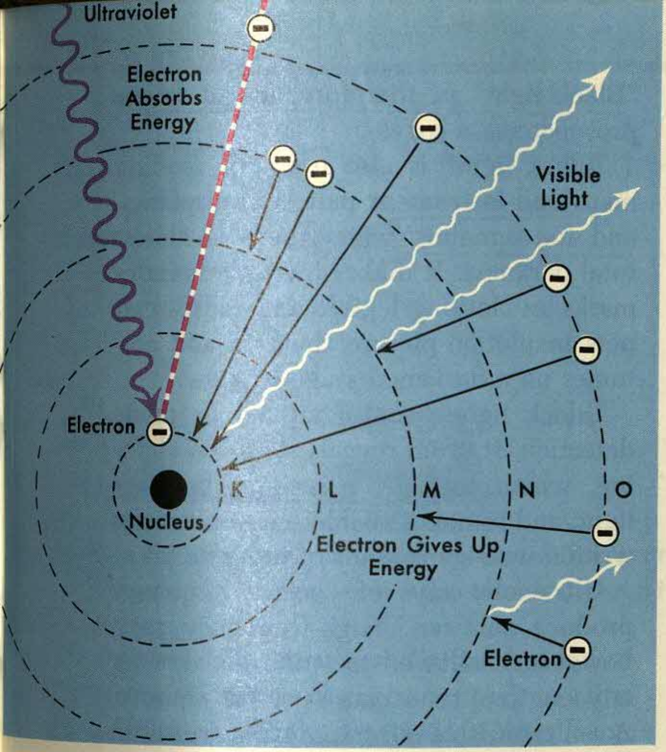
Sources of Infrared Rays

The principal natural source of infrared rays is the sun. Even on a cloudy day, some infrared rays from the sun reach the earth. Any material that is heated gives off infrared rays in usable amounts. A fireplace, a lamp bulb, an electric toaster, and a hot oven are examples. The frequency of the rays produced depends upon the temperature of the substance.

Most electric lamps produce infrared rays, but some are especially constructed to produce a larger amount of infrared rays, which can be concentrated on the object to be heated. The type of infrared lamp that has a clear glass bulb with a metal reflector inside it gives off a considerable amount of visible light. A lamp that has a ruby-red glass bulb reduces the amount of visible light.

Characteristics of Four Types of Radiant Energy

Type of Energy	*Frequency Range in CPS*	*Wave Length Range in Centimeters*	*Quantum Energy Range in Ergs*
Infrared	7.5×10^{11} to 3.75×10^{14}	4×10^{-2} to 8×10^{-5}	46×10^{-16} to 25×10^{-13}
Ultraviolet	7.5×10^{16} to 2.5×10^{18}	4×10^{-5} to 1.2×10^{-6}	46×10^{-11} to 16×10^{-9}
X-ray	3×10^{15} to 5×10^{19}	10^{-5} to 6×10^{-10}	20×10^{-12} to 33×10^{-8}
Gamma	1.5×10^{18} to 3×10^{20}	2×10^{-8} to 10^{-10}	10^{-8} to 20×10^{-7}



"Black light" makes certain minerals fluoresce.

American Museum of Natural History

When electrons go from a higher energy level to a lower one, they give off light. When they go to a higher one, they gain potential energy.

Infrared Rays at Work

The most common use of infrared rays is to produce warmth for human comfort. Some buildings are heated entirely by infrared rays of radiant energy.

Infrared rays are used to hasten the drying of paint. And during cold weather, infrared generators are used in citrus fruit groves. The infrared rays, traveling from the generator through the cold air, produce heat in the fruit. The fruit is thus kept from freezing even though the temperature of the surrounding air is below the freezing point.

Films sensitive to infrared rays are used in photography. They can take pictures in total darkness and also at long distances. By comparing the two pictures on page 197, you can see how much more effective infrared rays are than visible light rays for this purpose.

ULTRAVIOLET RAYS

Ultraviolet rays contain more energy than light. Although some of the lower-frequency rays are in sunshine, your eyes are not sensitive to them. They became known to man because of the germ-killing effect of sunlight that could not, at first, be explained.

Sources of Ultraviolet Rays

The greatest natural source of ultraviolet rays is the sun. However, when sunlight reaches the earth, it no longer possesses all of the ultraviolet rays which were present before it entered the earth's atmosphere. It is fortunate for man that the shorter ultraviolet rays are absorbed by the atmosphere, for many of them would burn the body if it were directly exposed to them.

Ultraviolet rays can be produced artificially by specially designed electric lamps. One such lamp, called a ***sun lamp,*** consists of a tungsten filament supported in a bulb made of a special type of glass and containing a small pool of mercury. When an electric current is passed through the filament, the filament heats the mercury, changing some of it to vapor. A stream of electrons passing through the vapor adds energy to the mercury atoms so that many of them reach an excited state. Electrons moving through the nucleus (see page 197) give rise to ultraviolet rays. The spectrum of ultraviolet rays from a sun lamp is about the same as the sun's spectrum.

Effects of Ultraviolet Rays

Ultraviolet rays of certain frequencies are often called "black light." Though they are invisible, they often cause many substances to glow, or fluoresce, with characteristic colors. When illuminated with ultraviolet rays, ores containing uranium, tungsten, zinc, and mercury, for example, give off visible light of different colors. "Black light" is, therefore, useful to ore prospectors.

"Black light" is also used for reading maps and instrument panels in airplanes, and for signaling when there is almost total darkness. It makes invisible laundry marks on clothing legible and causes carpets in motion-picture theaters and costumes on a darkened stage to glow.

"Black light" is also an aid in crime detection. It often reveals stains on clothing, which cannot be seen in ordinary light, and it makes visible secret messages written with some kinds of invisible ink.

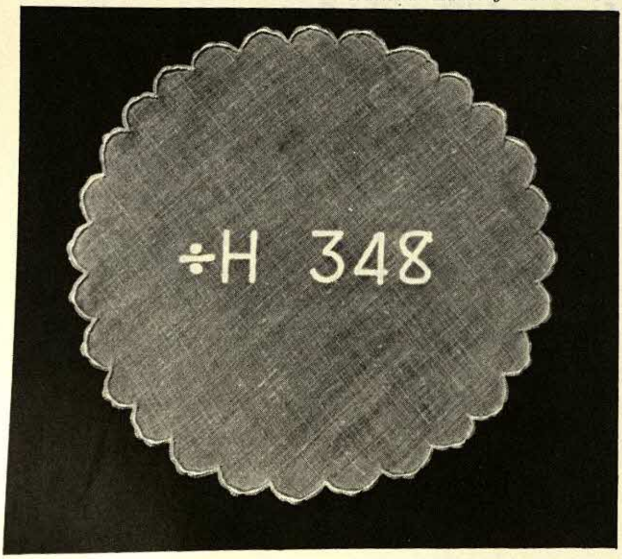
Ultraviolet rays of certain frequency produce sun tan. High-frequency rays, however, if allowed to strike the skin for any length of time, cause painful sunburn. A sun tan with a minimum of sunburn can be acquired in two ways. One way is to begin by exposing the skin to sunlight, or a sun lamp, for very short periods of time and gradually increasing the time of exposure until the skin is satisfactorily tanned. The other way is to use a sun-tan cream or lotion which absorbs the higher-frequency ultraviolet rays which burn the skin, but which allows only the lower-frequency rays to reach it. Not all sun-tan preparations effectively prevent sunburn.

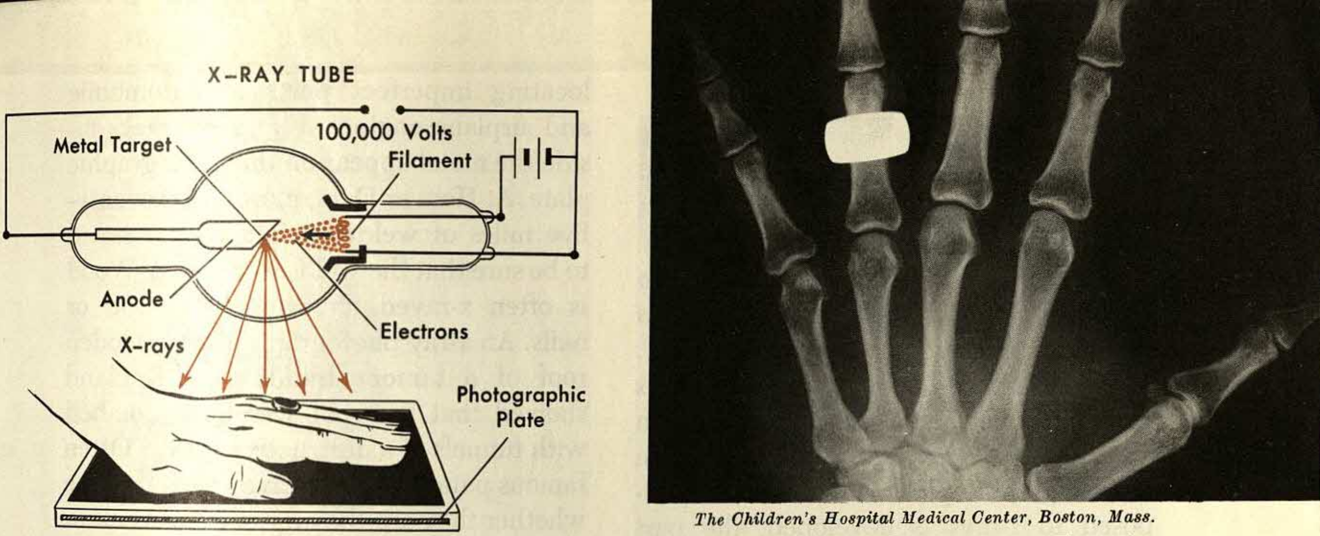
Vitamin D, sometimes called the "sunshine vitamin," is produced in the body only when a person is exposed to ultraviolet rays, but sun baths are not necessary for its production. Tests with both children and adults have shown that in summer sufficient vitamin D is produced if a person dressed in street clothes spends some time each day in the open.

Ultraviolet rays are also used to increase the vitamin D content in certain foods by

"Black light," or ultraviolet rays, directed at doily below, made invisible marks visible.

National Marking Machine Co.





The Children's Hospital Medical Center, Boston, Mass.

In the x-ray tube, left, high voltage drives a stream of electrons from the tungsten coil to the anode and thus causes emission of x-rays. At right is an x-ray photograph of hand wearing ring.

a process known as ***irradiation.*** Irradiation consists mainly of exposing foods to ultraviolet rays for short periods of time. Large amounts of food, especially canned milk, receive this treatment to increase their vitamin D content.

Certain of the higher-frequency ultraviolet rays generated by a special ***germicidal lamp*** are powerful germ killers. Germicidal lamps are used for sterilizing water, the air in hospital operating rooms, schoolrooms, public buildings, homes, refrigerators, surgical-instrument cases, and so on. They must be installed with care so that their rays will not harm the eyes. Their rays also discolor many materials. Some types of white plastic, for instance, turn brown or gray under them. Growing plants can be badly damaged by them.

X-RAYS

You are probably familiar with the use of x-rays to take pictures of broken bones. Perhaps you do not know that x-rays have many other uses, especially in industry. They have, for example, made automobiles safer by revealing imperfect parts that are removed and replaced. It is important that you understand how your life has been affected by the use of this valuable form of radiant energy.

Production of X-rays

X-rays were discovered in 1895 by Wilhelm Roentgen, a German scientist. Although Roentgen discovered some of their important properties, he did not know what the rays were. He therefore called them x-rays, the x standing for their unknown nature. Today scientists believe that x-rays are radiant energy of extremely high frequency and, therefore, of extremely short wave length.

X-rays are produced when rapidly moving electrons strike a piece of metal inside a tube from which the air has been removed. A careful study of the diagram of a small x-ray tube, above, will show you the principle on which it operates.

Characteristics of X-rays

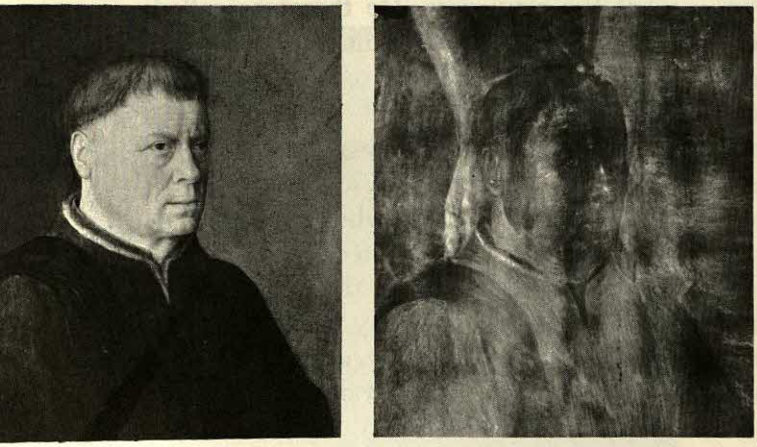
X-rays can be used for taking pictures because of two important characteristics. One characteristic is that they do not pass through all substances to the same extent. A bone, for example, stops more rays than does flesh. A metal ring or bracelet stops even more than does bone. See page 201.

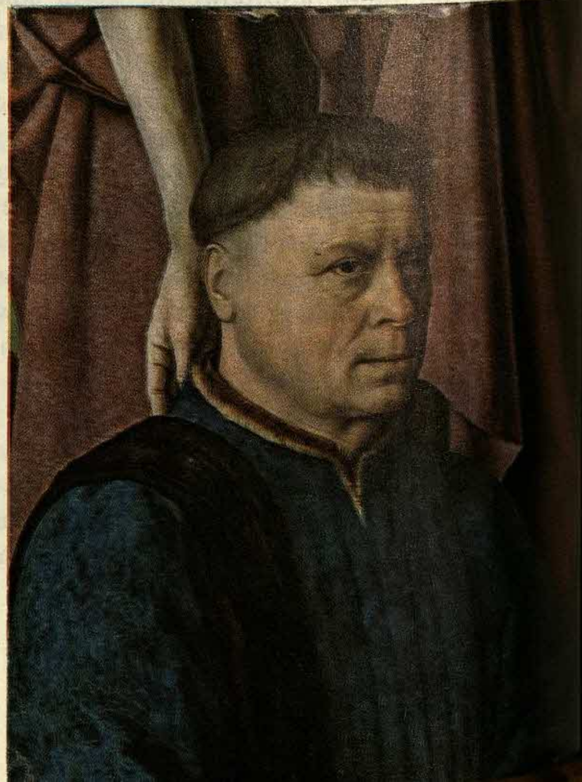
The second characteristic of x-rays is that they affect a photographic plate in the same way that light affects it. When a photographic plate which has been exposed to x-rays is developed, the part where the greatest number passed through appears darker than where only a few passed through. A shadow picture of the interior of the exposed object is obtained.

X-rays at Work

X-ray pictures are taken for many purposes. They are an accurate means of locating imperfect parts in automobile and airplane engines. Flaws or cracks inside the metal appear on the photographic plate. At Hoover Dam, more than seventy-five miles of welded joints were x-rayed to be sure that the welds were good. Wood is often x-rayed for wormholes, rot, or nails. An x-ray photograph of the wooden roof of a famous building in England showed that the roof was honeycombed with tunnels of a destructive beetle. Often famous paintings are x-rayed to determine whether they are the originals, or whether they are forgeries. Many forged paintings have been discovered with x-rays.

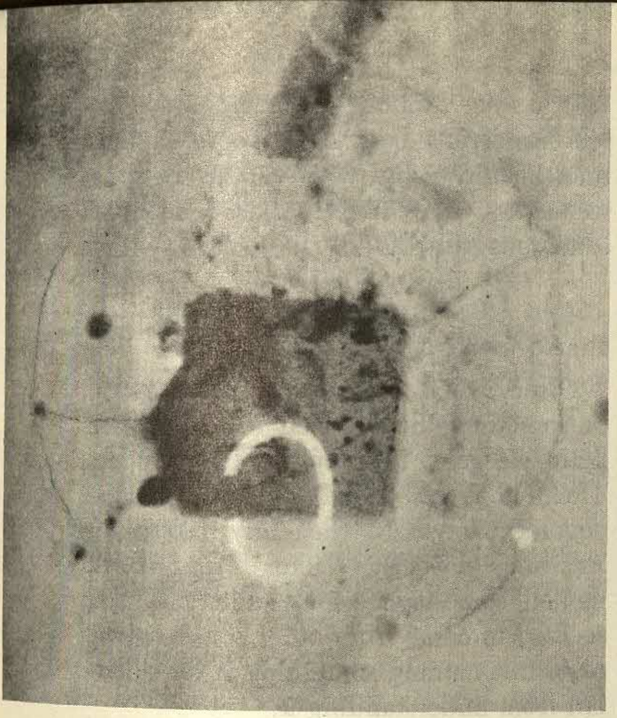
The most important use of x-rays is in the diagnosis and treatment of disease. X-ray pictures of the lungs, for instance, show whether a person has tuberculosis. Some diseases of the stomach and other internal organs can be diagnosed by the





At left is a photograph of an eighteenth-century portrait, taken before x-ray and cleaning. In the center is an x-ray of this painting, which reveals an arm behind the sitter. At right is painting, restored as result of x-ray study.

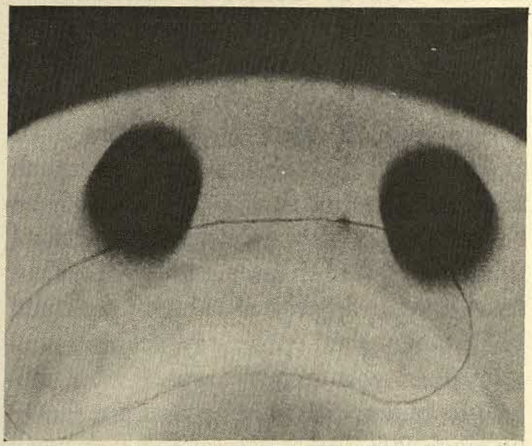
Three photographs from The Metropolitan Museum of Art—The Michael Friedsam Collection, 1931



use of x-ray pictures. X-rays are also helpful in treating diseases such as cancer.

Often there is no need for a permanent record of an x-ray examination. In such cases, an object is placed so that the x-rays passing through it strike a screen coated with certain chemicals which glow when x-rays strike them. A shadow picture of the object appears on the screen, which is called a ***fluoroscope.***

Fluoroscopic examination is especially valuable when large numbers of similar objects must be inspected for a specific purpose. Golf balls, for example, are fluoroscoped to see if the core is properly centered. By use of the fluoroscope, juicy citrus fruits can be separated from the crystallized fruits. Boxed and bulk foods are examined for foreign matter such as wire, bits of metal, and stones. Cigarettes can be counted inside a package by means of a fluoroscope.



Canadian Radium and Uranium Dir.—
Canrad Precision Ind., Inc.

Gammagraph at left shows excessive shrinkage in strip of cast steel tubing. Defects are also revealed in casting at top.

GAMMA RAYS

Gamma rays contain the most energy of any type of radiant energy which displays wave characteristics. Scientists believe this to be so because rays are not deflected by a magnetic field as are other types of radiant energy. They were first identified in connection with radioactive decay. See Unit 2, page 58.

Production of Gamma Rays

Practically the only usable source of gamma rays is from the disintegration of natural, or artificial, radioactive materials. Radium salts were used before the development of nuclear reactors. Since that time, various elements have been made radioactive in nuclear reactors and shipped to their point of use. Of course, some of the energy of atomic bombs is emitted as gamma radiation. But production of gamma rays by bombs is uncontrolled and results in severe destructive effects.

Uses of Gamma Rays

Gamma rays affect photographic films as do x-rays. However, they are much more penetrating than x-rays. They have been detected after passing through more than thirty centimeters of steel. Thus flaws deep inside the metal, which cannot be photographed with x-rays, can be photographed with gamma rays. Two radiographs taken with gamma rays are shown on page 203.

Gamma rays destroy cells by changing some of the molecules in them. These cells lose their power to divide, and then growth becomes impossible. When radiation is severe enough to affect many cells, ***radiation sickness*** results. If less than a lethal dose of radiation has been received, the person begins to recover when the remaining cells resume their division.

It has been found that gamma rays affect cancerous body cells more rapidly than healthy cells. Thus gamma rays, as well as x-rays, are used in the treatment of cancerous growths.

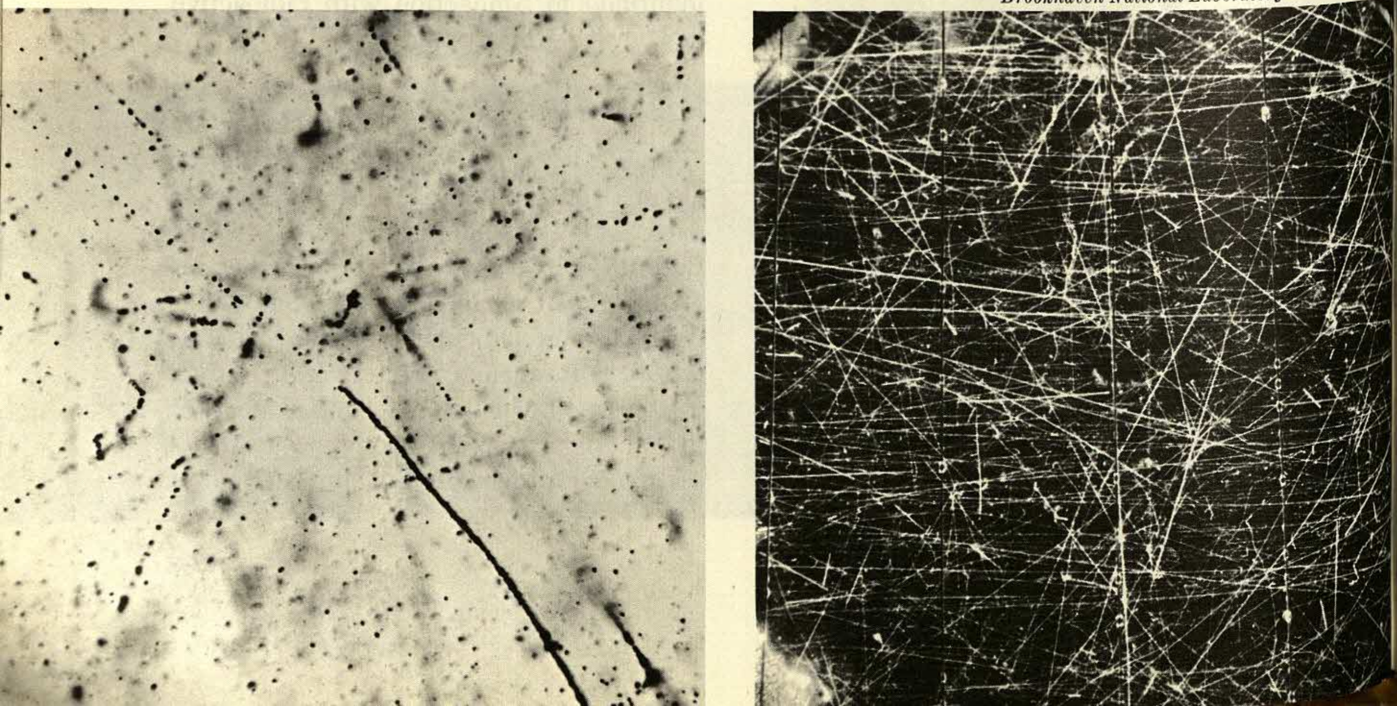
COSMIC RAYS

Often, when man first becomes aware of something new which he cannot explain, he gives it a representative name. Thus, Roentgen called the rays he discovered x-rays. In the early 1900's, an Austrian physicist, Victor Franz Hess, named some mysterious radiations that seemed to come from outer space ***cosmic rays.*** But naming something is far different from understanding it.

Although scientists now know more about cosmic rays than they did when they were named, they still are not sure how these rays originate in space. It was thought originally that cosmic rays were

Secondary cosmic ray, K Meson, left, produced by Cosmotron, comes to rest in emulsion and decays into fast, positively charged light meson. At right are other high-energy particles.

Brookhaven National Laboratory



a higher energy type of radiant energy than gamma rays. Thus they were shown on the electromagnetic spectrum. Now, however, they are thought to be particles of extremely high energy which bombard the earth from outer space. As they enter the outer reaches of the earth's atmosphere, they are known as ***primary*** cosmic rays. These rays usually collide with some atomic nucleus in the atmosphere. The various kinds of matter and energy coming from the collision are known as ***secondary*** rays. Almost all of the cosmic rays reaching the earth are secondary rays. They come from all directions in outer space.

Primary Rays

Evidence of primary cosmic rays has been obtained by sending photographic films to altitudes of 90,000 or more feet. Occasionally, a primary ray will collide with an atom on the film. When this happens, secondary rays are produced. These rays move away from the collision point, affecting the film as they go. When the film is recovered and developed, the paths of the secondary rays appear as lines in the photograph. Analysis of many such photographs leads scientists to estimate the energy of primary cosmic rays to range from 10^{12} to 10^{15} electron volts ($1 \text{ electron volt} = 1.6 \times 10^{-12}$ ergs). Photographs of some particles in cosmic rays are on page 204.

It is estimated that between 50 and 200 primary cosmic rays pass through one square inch of space above the earth each minute. The intensity of cosmic radiation is least near the equator and increases steadily toward the magnetic poles of the earth. How do you think this difference in intensity might be explained?

Secondary Rays

Secondary cosmic rays consist primarily of positive and negative electrons, neutrons, ***mesons,*** and gamma rays. Although the word electron is commonly used to designate the negative electron (***negatron***), there are also positive electrons (***positrons***). A meson is a particle having a mass between an electron and a proton. These are all high-energy particles. In fact, their high energy was responsible for their discovery. They have been detected 900 feet under water and in a mine 1,600 feet below the earth's surface. Ordinary gamma rays cannot penetrate matter to this extent.

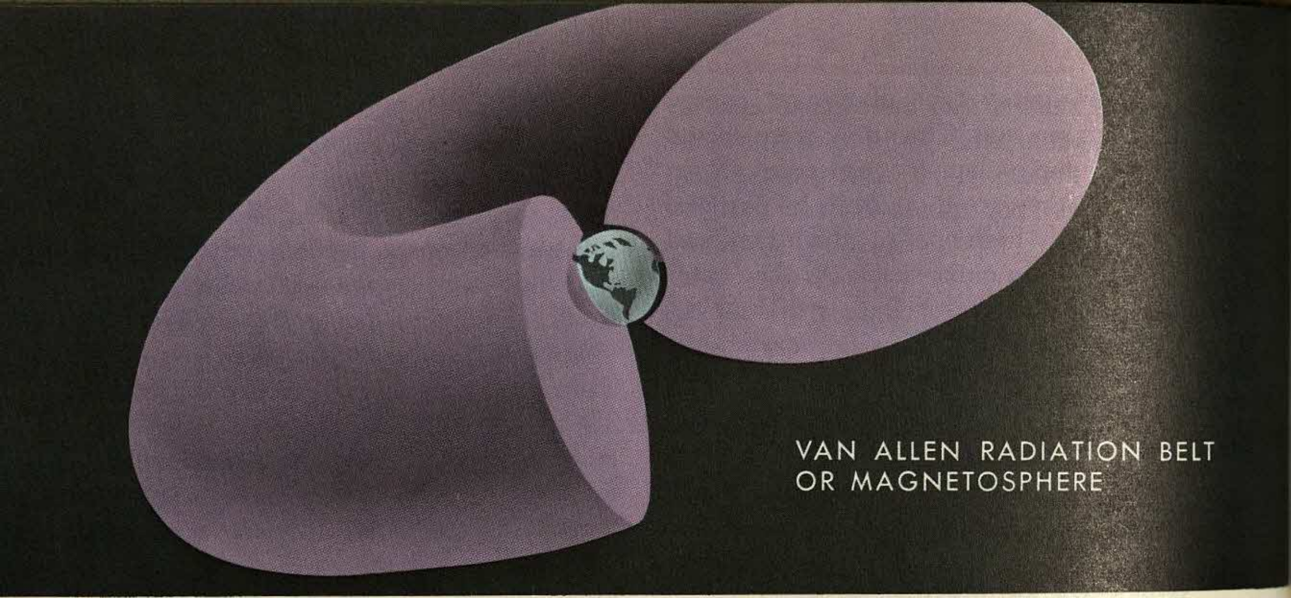
Van Allen Radiation Belt

Cosmic rays are among the least understood aspects of man's environment. They have no practical use at the moment. Their number, distribution, and energy are being studied with the various types of space probes being launched by different countries of the world.

Dr. James Van Allen, director of the instrumentation for cosmic ray studies in the United States satellite and space programs, has mapped a region around the earth where cosmic reaction is most intense. This doughnut-shaped region is known as the Van Allen radiation belt. It is based upon the data obtained from space probes. See the diagram of this belt on page 206.

SUMMARY

Infrared rays are most important to mankind because of their ability to radiate heat. Although the sun is our principal



VAN ALLEN RADIATION BELT OR MAGNETOSPHERE

source of infrared rays, any heated material produces them. The rays are widely used in industry because of their heating effects. Waves of infrared energy are longer than those of light and are less affected by the atmosphere. With film sensitive to infrared rays, photographers take pictures in total darkness. They can, therefore, be used in photography when it is important to get clear pictures of objects in the distance.

Ultraviolet rays are of a type of radiant energy which can be obtained naturally from sunlight, or produced artificially by exciting mercury atoms with streams of electrons. They are used to produce vitamin D in the body and in certain foods. Certain of the ultraviolet rays are effective in destroying disease-producing germs, although these rays must be carefully controlled, since they also have a harmful effect upon the body. When ultraviolet rays strike the atoms of certain substances, the atoms become excited and give off a colored light characteristic of the kind of atom that is excited. It is thus possible to use ultraviolet light in discovering precious ores.

X-rays are a form of radiant energy produced by atoms of certain substances when bombarded by electrons. It is possible to produce and control x-rays in order to take pictures of the interiors of solid objects. When permanent pictures are not desired, the interior of objects can be examined with a fluoroscope.

Gamma rays, the most energetic of all types of radiant energy, are produced by disintegration of atomic nuclei. They are used to take pictures of the interior of metals not reached by x-rays, and in medicine. Much of the damage of nuclear explosions is caused by gamma radiation.

Primary cosmic rays originate in outer space. They seem to be highly energetic particles that cause nuclear disintegration as they enter the earth's atmosphere. Secondary cosmic rays are produced in the disintegration. Only secondary cosmic rays are observed near the earth's surface. Matter is not penetrated to this extent by ordinary gamma rays.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Infrared rays (a) have higher frequency than light (b) have less energy quanta than light (c) have a shorter wave length than x-rays (d) come from the disintegration of a nucleus.

2. The source of ultraviolet rays in a sun lamp is the (a) glass (b) electric discharge (c) atoms of mercury vapor (d) tungsten.

3. Miners use ultraviolet light for (a) sun tan (b) prospecting (c) vision at night (d) reaching a greater depth.

4. The health benefit derived from summer sunshine is (a) vitamin D (b) sun tan (c) sunburn (d) "black light."

5. The vitamin D content of foods is often increased by (a) boiling (b) storing (c) irradiating (d) broiling.

6. It is known that ultraviolet rays are present in sunshine because (a) they can be seen (b) they can be felt (c) of the effects they produce (d) they kill germs.

7. Compared with ultraviolet rays, the frequency of x-rays is (a) lower (b) higher (c) the same (d) shorter.

8. The substance which will absorb x-rays the most is (a) flesh (b) bone (c) metal (d) cloth.

9. When a permanent record is not wanted, the instrument used for examination with x-rays is the (a) fluoroscope (b) microscope (c) camera (d) germicidal lamp.

10. X-rays are dangerous if not properly used because they (a) kill cells (b) affect photographic plates (c) are easily produced (d) have a high frequency.

B. Checking Generalizations

Below are listed several facts about the way different types of radiant energy, about which you have read in this unit, are produced. Following the set of facts are three generalizations. On your answer sheet, write the letter of the generalization which is best supported by all preceding facts listed.

FACTS

1. Rapidly moving electrons may produce x-rays when they strike the atoms of a metal target.

2. Electrons striking atoms of mercury inside a fluorescent lamp produce ultraviolet rays.

3. When the atoms of a metal stove are heated, infrared rays are given off.

4. When the metal filament of an incandescent lamp is heated white hot, it produces light.

5. When ultraviolet rays fall upon the atoms of certain chemicals, visible light is given off.

GENERALIZATION

a. Atoms can be excited in various ways so that they will produce different types of radiant energy.

b. Radiant energy affects substances in different ways.

c. Many uses have been found for the different types of radiant energy man has been able to produce.

Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the more important ideas in this unit.

1. What is meant by the electromagnetic spectrum?
2. Why is the velocity of radiant energy in a vacuum a theoretical value?
3. In what way could a jet plane traveling faster than sound be compared to a particle producing Cerenkov radiation?
4. Why is it believed that radiant energy follows the principle of the inverse square even though measurements do not fit the principle precisely?
5. Upon what evidence is the conclusion based that radiant energy can do work?
6. Why should energy be described as "having wave characteristics" rather than as "being a wave"?
7. How do electric fields resemble and differ from magnetic fields?
8. How can a tuned circuit generate electromagnetic waves?
9. What is the corpuscular theory of light?
10. Why is it necessary to use a particle model for radiant energy?
11. Why did de Broglie suggest a guiding-wave model?
12. How does AM differ from FM?
13. How does radar operate?
14. Which model of radiant energy is most useful for explaining diathermy? Why?
15. What is the difference between refraction and reflection?
16. What explanation is given for the production of high-frequency energy with the Bohr-Stoner model of the hydrogen atom?
17. What are the main differences between the traditional and the Land theories of color?

18. How does nearsightedness differ from farsightedness?

19. How does television make use of persistence of vision?

20. What infrared ray effect is considered to be most important for man? Why?

21. In connection with ultraviolet radiation from the sun, of what value is the atmosphere to mankind?

22. What gamma ray and x-ray effects are similar?

23. How do cosmic rays differ from the type of radiant energy included in the spectrum?

B. APPLYING YOUR KNOWLEDGE

1. Below are listed a number of generalizations about radio waves. Following them are listed a number of statements describing situations in which radio waves are used. After the letters of each situation, write on your answer sheet the number of each generalization which helps explain the situation.

GENERALIZATIONS

1. Radio waves travel at about 186,000 miles per second.

2. Radio waves may be reflected from, transmitted through, or absorbed by the objects they strike.

3. Radio waves can travel through empty space.

SITUATIONS

a. Radar has been used to contact the moon.

b. Communication between distant parts of the world is almost instantaneous when radio waves are used.

c. Reception from an automobile radio often fades away when the automobile passes under bridges or trestles.

d. Many radios do not have outside antennae.

e. Radar can be used to locate the distance and position of objects.

2. Another important generalization developed in this unit is: The atom is the source of radiant energy. On your answer sheet, write letters of statements below that support this generalization.

a. Under certain conditions when electrons fall from an outer energy-level orbit to an inner energy-level orbit, visible light is produced.

b. Radiant energy can travel through space.

c. When electrons are caused to move back and forth in a circuit, they may produce radio waves.

d. An excited atom may give off several different types of radiant energy.

e. Silver is a good conductor of an electric current.

f. Molecules of compounds are made up of atoms.

3. On your answer sheet, write a letter for each of the situations listed below. After each of these letters, write the number of the generalization which helps explain the situation.

GENERALIZATIONS

1. Light may be reflected from, transmitted through, or absorbed by, the object it strikes.
2. Light travels in straight lines.
3. Light may change its direction when it passes from one material to another.

SITUATIONS

a. The ceilings of rooms are usually painted a light color.

b. Storage bottles for some chemicals are made of colored glass.

c. Eclipses of the sun occur when the moon passes between the sun and the earth.

d. Ponds of clear water often appear to be shallower than they really are.

e. Many eye defects can be corrected by using lenses.

4. Six types of radiant energy are listed below. Rearrange them in order of increasing wave length by placing the one with the shortest wave length first and the longest last.

a. light
b. gamma rays
c. radio waves
d. x-rays
e. infrared rays
f. ultraviolet rays

You Can Go Further

A. BY TESTING A HYPOTHESIS

In the experiment on page 196, it was assumed that the color of sunglasses does not affect clarity of vision. As long as you are willing to accept this statement as true, it is an assumption. But if you should want to be sure it is true, you might treat it as a hypothesis and test it. On your answer sheet, write the numbers of the statements which describe the best procedures for testing this hypothesis.

1. Test, by the method used on page 196, both expensive and inexpensive sunglasses of the same color.

2. Test, by the method used in the same experiment, inexpensive sunglasses of many different colors.

3. Test, by the same method, expensive sunglasses of many different colors.

4. Test, by the method used in the same experiment, both expensive and inexpensive sunglasses of different colors.

B. BY RECOGNIZING ASSUMPTIONS

1. If you should conclude from the evidence obtained in the experiment on page 196 that sunglasses vary in their effect upon clarity of vision, there is at least one other assumption you will have to accept in addition to those listed in the experiment. On your answer sheet, write the number of the sentence below which best states that assumption.

a. Expensive sunglasses are always better than inexpensive ones.

b. The sunglasses tested will affect the image on the retina of the eye in the same way they affected the image on the screen.

c. All inexpensive sunglasses affect the image on the screen in the same way.

2. Since it has been observed that radiant energy and gravitation conform to the inverse square principle or law, it is believed that radiant energy and gravitation are closely related. On your answer sheet, write the letters of the statements below which may be accepted as assumptions before you could believe this.

a. Atoms are involved in both.

b. All things in the universe are governed by one physical law.

c. Radiant energy has both magnetic and electric properties.

d. Things are related when they exhibit similar properties.

e. Radiant energy and gravitation are phenomena exclusively restricted to the earth.

f. Everything conforms to the inverse square principle.

g. The inverse square principle explains why gravitation and radiant energy have similar properties.

h. Both gravitation and radiant energy have wave characteristics and particle characteristics.

3. In several places in this unit, reference has been made to the scientist using a model to explain phenomena related to radiant energy. On your answer sheet, write the letter of the statements below which the scientist is making whenever he uses a model.

a. There is order in the universe.

b. There are many things about radiant energy and other natural phenomena that man will never be able to understand.

c. Reducing abstract ideas to concrete structures or forms helps to make the ideas clearer.

d. Atoms are the basic units of which all matter is composed.

e. If you can't reduce your idea to a model, then you don't have an idea.

f. Most people are not sufficiently intelligent to understand science ideas without using models.

C. By Preparing Written Reports

Refer to encyclopedias or physics books to get information for reports on the following subjects.

1. Cerenkov radiation
2. The electron microscope
3. Land color theory
4. FM radio broadcasting
5. Measuring the velocity of light
6. The spectroscope
7. Radiant energy in criminology
8. Cosmic rays
9. The origin of gamma rays
10. Communication relay satellites

D. By Conducting a Study

Make a survey of illumination in your school. If you find that any improvements are needed, prepare a report on the recommendations you would make.

E. By Reading

Aisberg, E. *T.V.—It's a Cinch.* New York: Gernsback Library, 1957.
Informative introduction to television.

American Radio Relay League. *How to Become a Radio Amateur.* West Hartford, Conn.: American Radio Relay League, 1959.
All the information pupil will need to become a ham operator.

Birren, Faber. *New Horizons in Color.* New York: Reinhold Publishing Corp., 1955.

Provides the pupil with a greater understanding of color in its relation to science.

Bitter, Francis. *Magnets.* Garden City, N.Y.: Doubleday and Company, Inc. (Anchor Books), 1959.

Probes field of magnetism.

Cook, J. Gordon. *We Live by the Sun.* New York: Dial Press, 1957.

Story of the sun and its service to man. Color, speeds, and many other phases of the sun's energy are discussed.

Cook, J. Gordon. *Electrons Go to Work.* New York: Dial Press, 1957.

A study of the role these particles play in electronic experiments, concepts, and practical devices.

Crowther, J. O. *Radioastronomy and Radar.* New York: Criterion Books, 1961.

Discussion of developments in fields of radar and radioastronomy.

Efron, Alexander. *Light.* New York: John F. Rider Company, 1956.

Describes properties of light and various theories concerning it.

Faraday, Michael. *On the Various Forces of Nature.* New York: Thomas Y. Crowell Company, 1961.

Science classic, plus easy-to-follow experiments.

Lewelleyn, John. *Understanding Electronics From Vacuum Tube to Thinking Machine.* New York: Thomas Y. Crowell Company, 1957.

Clear introduction to subject of electronics.

Mach, Ernst. *The Principles of Physical Optics.* New York: Dover Publications, Inc., 1958.

Minnaert, M. *The Nature of Light and Color in the Open Air.* New York: Dover Publications, Inc., 1954.

Explains hundreds of phenomena.

Oldfield, R. L. *Radio-Television and Basic Electronics.* Chicago, Ill.: American Technical Society, 1956.

For pupils who wish to go further in study of electronics.

Osmond, Edward. *From Drumbeat to Ticker Tape.* New York: Criterion Books, 1961.

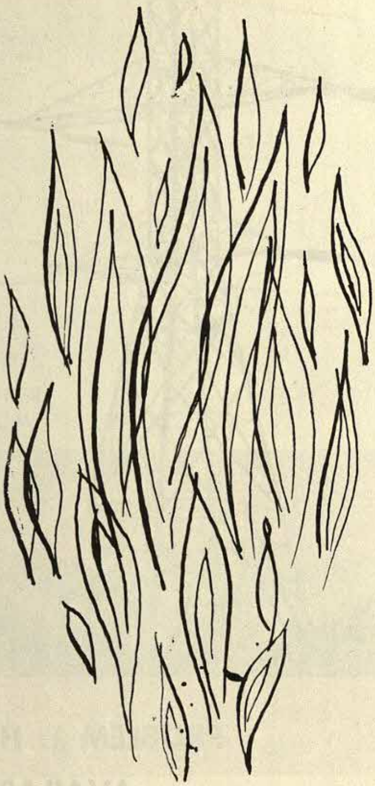
History of human communication.

Pierce, John R. *Electrons, Waves, and Messages.* New York: Doubleday and Company, Inc., 1956.

Describes science of electronics and electronic communication.

P&H

Shostal



Unit 5

Electricity and Heat

Many of the ideas which you learned in earlier units will be used in this unit to help you get a better understanding of two important types of energy: electricity and heat. You will learn how electricity is explained by using the old familiar model of the atom. You will learn how a similar method is used to explain heat.

Before scientists could go far in describing such phenomena as electricity and heat, ways of measuring them had to be devised. Measurement made it possible to carry on experiments that lead to better understanding as well as better methods of controlling electricity and heat.

Bonneville Power Administration

PROBLEM 1: HOW IS ELECTRICITY MADE AVAILABLE FOR MAN'S USE?

Electricity is an amazing form of energy. It travels at high speed through wires that seem to be solid. You are convinced of this fact because electric devices operate when attached to these wires. Yet you cannot see electricity—even with the most powerful microscope. Just the same, you would like to be able to understand electricity more completely. To help you understand it, scientists create some sort of mental model to represent electricity.

ELECTRICITY AS ENERGY

Imagine that you could magnify the inside of a copper wire millions of times. Then suppose you could see inside this wire with a sort of x-ray vision. A description of what you might see becomes a mental model for the wire and the electricity in it.

First you would see huge numbers of copper atoms. Scientists estimate there are about 10^{22} atoms in each cubic centimeter of copper. At the center of each atom you would see a bundle of sixty-three protons and neutrons. There would be twenty-eight electrons spinning like tops as they whirled about the nucleus in the first three electron orbits, or shells. A lone electron would be in the fourth shell.

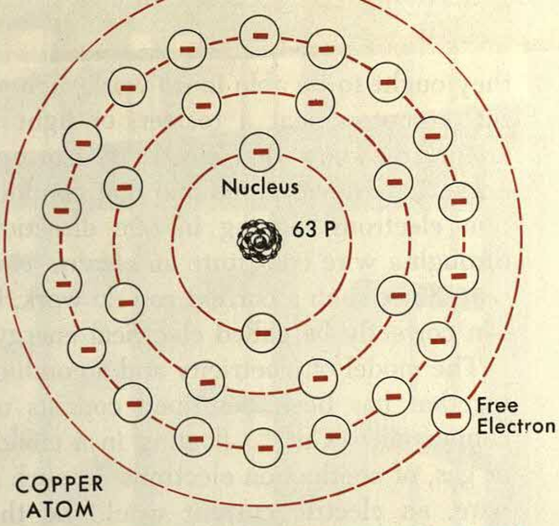
In spite of the huge number of atoms, there would be considerable space inside the wire. You would also note that the atoms are not located haphazardly, but in a regular pattern. They form ***microcrystals,*** which fit together in such a way that the copper seems solid. Closer examination reveals that each atom is not perfectly still. It vibrates about in a small space near its permanent location.

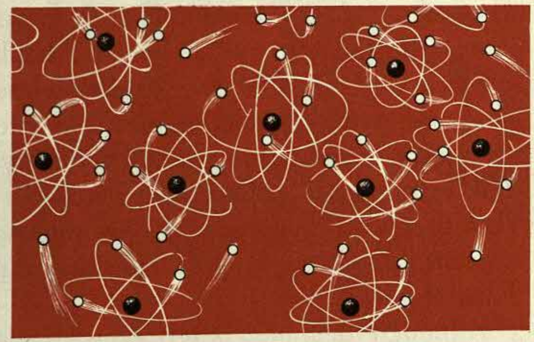
You would also see swarms of electrons darting about in the space between atoms. They no longer seem to be firmly attached to a nucleus. They are called ***conduction electrons.*** (See column 2.)

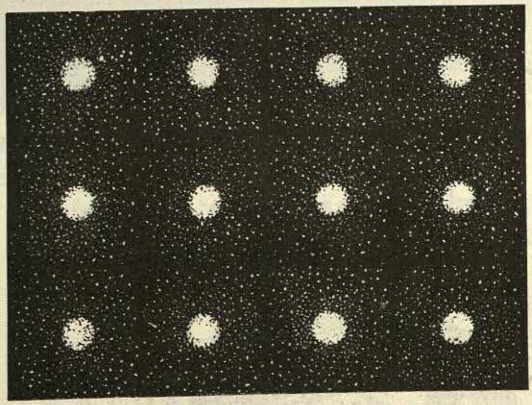
You would see that many of the copper atoms do not have the electron you would expect to find in the fourth shell. With this electron missing, all of the copper atoms become ions. Evidently their outermost electrons had so much energy, they broke away from the atom to zoom about in space between the atoms. These are probably the conduction electrons. There seem to be billions and billions of conduction electrons in every cubic centimeter of copper.

As you watch the conduction electrons for a time, you can see no over-all pattern in their motion. They seem to be going off in every possible direction and at different speeds. If, while you are watching them, an electric field is brought near, what would you expect to see? An electric field is the space in which an electric force exists. Knowing that such a field exerts a force on electrons, you would expect vast numbers of them to start moving in one direction.

Inasmuch as the force acting on the electrons would move them a distance, work should be done. With work done on them, they would take on extra energy from the field. With this extra energy,







Crystal Lattice

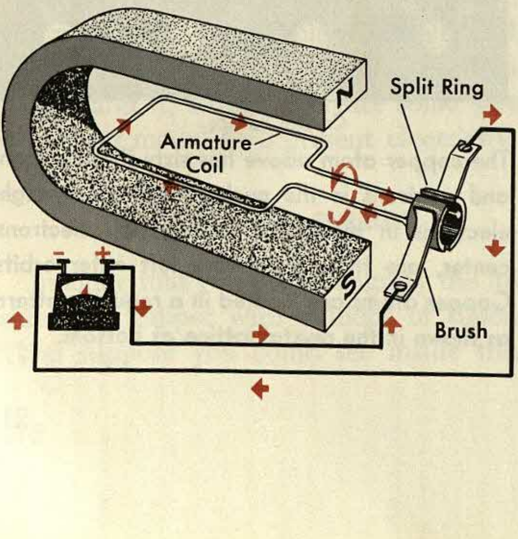
The copper atom above has sixty-three protons and neutrons in the nucleus and twenty-eight electrons in the orbits. Conduction electrons, center, are those that have left outer orbits. Copper atoms are located in a regular pattern, as shown in the crystal lattice at bottom.

they ought to be able to do work such as run a motor, heat a toaster, or light a lamp. You know that electricity can operate these devices. Assume that conduction electrons moving in one direction through a wire constitute an ***electric current.*** Since such a current can do work, it can correctly be called electrical energy.

The model of electricity and a conductor that has been described consists of copper ions (Cu^{++}) floating in a cloud, or gas, of conduction electrons. In such a wire, an electric current would be the movement of the conduction electrons under the influence of an electric field. Because work must be done to change the random-moving conduction electrons into an electric current, they gain extra energy. This extra energy enables the electric current to do observable work. An electric current, therefore, can be considered a form of energy.

Although the model described is known to represent electricity and its conductor accurately in some respects, it is inaccurate in others. Do not fool yourself into thinking that the model is a description of what really is in the wire. The model should remain imaginary.

DC GENERATOR



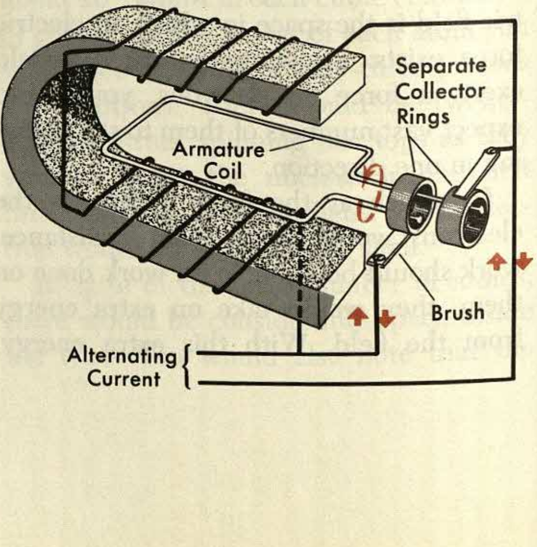
Conductors and Insulators

You have assumed that a conductor has an abundance of conduction electrons at ordinary temperatures. Billions can be moved along the wire. If a material has few conduction electrons at ordinary temperatures, only a few can be moved. The current would, therefore, be very small. In materials such as glass, rubber, and bakelite, the current is so small that it can usually be disregarded. Such materials are called ***insulators.*** However, if an insulator is heated, the number of conduction electrons is increased, and they may conduct enough electricity for the material to be considered a conductor.

Types of Electric Current

There are two types of electric current. In one type, the electrons always move in the same direction within the conductor. Although the conductor may be arranged in many positions, the electrons never change the direction of their movement within it. This type of electric current is usually called ***direct current*** (DC). It is seldom used in the home because it cannot be transmitted so easily as another type, ***alternating current*** (AC).

AC GENERATOR



TVA Photo

TVA powerhouse at Fontana Dam, N.C. Each generator has a capacity of 67,500 kilowatts.

In the second type of current, the direction of the motion of the electrons within the conductor is constantly being reversed. The electrons move back and forth within the conductor. Alternating current is used in most of our homes.

AC ELECTRICITY

The electricity for our homes is produced with machines called generators. These machines are really converters, rather than producers, of energy. They transform the energy of falling water, steam molecules, or fuel (including uranium) into electrical energy.

Generators

Although a generator, such as the one shown on this page, may look complicated, it has only two main parts, the ***armature*** and a number of magnets. The armature, consisting of numerous coils of copper wire, is surrounded by several magnets. Thus the armature is in a magnetic field, although it does not touch the magnets.

When the armature is rotated, its coils of wire cross the magnetic field of the magnets. In so doing, the force of the field does work on the conduction electrons in the copper wire. The force, at each instant of time, is directed in such a way as to move the electrons along the wire in the coils. Because the armature is rotating, any part of it cuts the field first in one direction and then in the other. The changing direction has the effect of reversing the electric field. This, in turn, results in an electron movement that continually reverses itself. The final outcome is an electric current moving first in one direction and then in another, which, as you know, is alternating current.

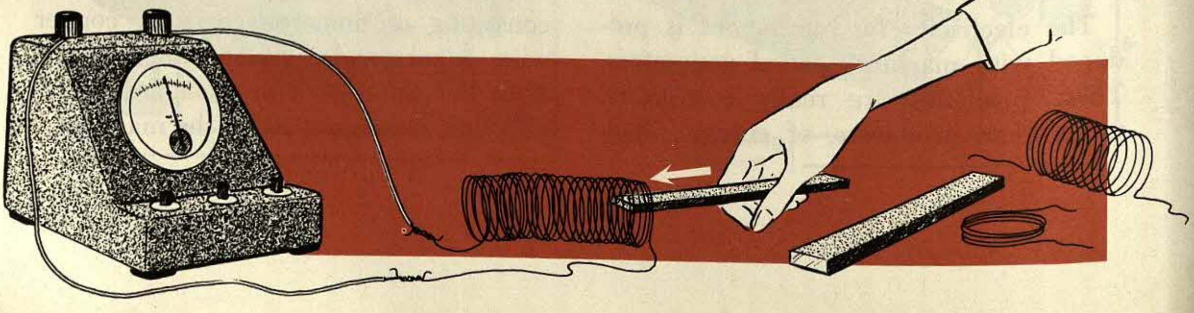
When the armature coils are stationary, there is no cutting across of the field, and, therefore, no force acting on the conduction electrons in the wire. They are said to have ***zero potential energy.*** They are ready to move whenever a force is applied.

As the armature moves again and crosses the magnetic field, the conduction electrons are acted upon by the field. They now have a potential energy other than zero. The difference between the two energy conditions is known as ***potential difference.*** For example, if the potential energy is zero when the armature coils are stationary and changes to some value, say 100, at one-fourth of a revolution, the 100 is taken as the potential difference resulting from the change in coil position. A potential difference is produced between the ends of the wire coils of the armature of a generator as a result of the work done in rotating the armature coils across the magnetic field. Potential difference must exist between two points in an electrical circuit. In this case, it would be between the ends of the wire of the armature coil. The method of measuring potential difference is explained in Problem 3.

If the armature wires are connected to an electric device such as a lamp, the varying potential difference (representing energy) across the armature moves electrons back and forth in the lamp. Some of their energy is transformed to heat and light in the lamp.

Form a twelve-turn coil of wire about two inches in diameter. Connect the ends of the coil to a *galvanometer.* A galvanometer is an instrument used to detect electric current. Insert one pole of a strong magnet inside the coil and then move the coil back and forth. Observe the action of the pointer of the galvanometer.

Vary the speed of the coil and the strength of the magnetic field. Try the other pole of the magnet inside the coil. With wire of the same diameter, make a coil of thirty-six turns and one of four turns. Connect these in turn to the galvanometer. Is there a difference?



How is the pointer on the galvanometer affected when the coil is moved through the magnetic field? How is the pointer affected when the direction in which the coil moves is changed?

What effect does strengthening the magnetic field, or putting two like poles together, have upon the movement of the pointer?

What effect does weakening the magnetic field, or putting two unlike poles together, have upon the motion of the pointer?

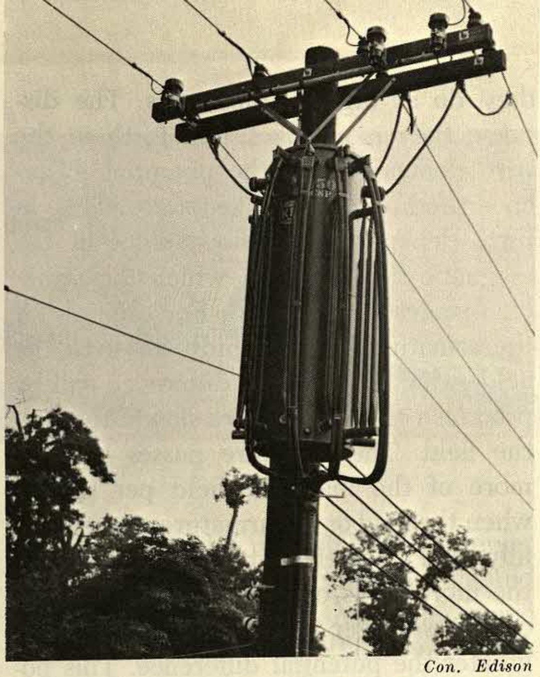
How does the number of turns of wire affect the movement of the pointer as the coil passes through the magnetic field?

State several relations between electric current in the coil and a magnetic field. List some basic assumptions you must accept in order to state the relations between the current and the field?

Characteristics of AC

Alternating current seems to be very much like radiant energy except that it travels almost entirely in a conductor rather than through space. Like radiant energy, it possesses electric and magnetic fields. These fields change in strength regularly in cycles, just as the radiant energy wave does.

The frequency of an alternating current is determined by the number of times each coil of wire on the armature passes completely through a magnetic field. If a single coil is moved completely through the magnetic field once each second, the current has a frequency of one cycle per second. If it is passed through the field ten times per second, the frequency is ten cycles per second. The AC frequency most commonly used in homes and factories in the United States is sixty cycles per second. For some purposes, however, AC frequencies as low as four cycles per second and as high as fifty billion cycles have been used.



Con. Edison

Metal box on utility pole, above, is step-down transformer. It decreases voltage of current so that it is safe for household use.

Alternating currents travel in copper wire almost as fast as radiant energy travels in space. Yet the electrons in an alternating current move back and forth near one point in a conductor. How, then, can the apparent high speed of AC be explained?

Like radiant energy, alternating current can be produced in varying amplitudes. The electrons move shorter distances each way at lower amplitudes than they do at higher amplitudes. The distance they move back and forth in the wire depends upon the potential difference produced by the generator. This, in turn, depends upon the amount of the magnetic field through which the armature passes each second. For example, if the armature passes rapidly through the field, a higher potential difference will be produced than if it passes slowly through the field. The armature passes through more of the magnetic field per second when the field or the armature rotates rapidly than when either rotates slowly. Also, the more turns of wire on the armature, or the stronger the magnetic field, the greater the potential difference. This potential difference is called the ***electromotive force*** (EMF), and is measured in units called ***volts.***

Distribution of AC

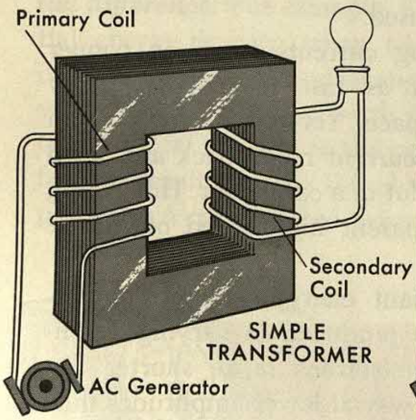
The electricity from a single power station can be distributed through a community or over an area covering several hundred square miles.

It has been learned that electricity can be sent long distances with less loss if the potential difference is high rather than low. Cross-country lines carry electricity at high potential difference—some as high as 440,000 volts. In order to distribute the electricity from such a high-voltage line safely through a city, the voltage is reduced to values ranging from 2,000 to 6,000 volts. It is further reduced to 220 volts, or 110 volts, before it enters, and is used inside, a home. Also for reasons of safety, as well as dependability and appearance, the complete electrical distribution system in some cities has been put underground.

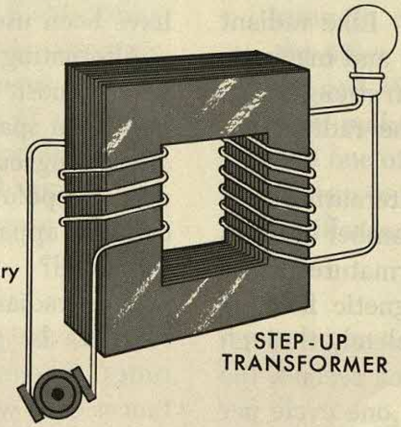
Transformer

A device called a ***transformer*** is used to change the voltage of electricity. A ***step-up*** transformer increases the voltage, while a ***step-down*** transformer decreases it. The construction of a simple transformer is shown on this page.

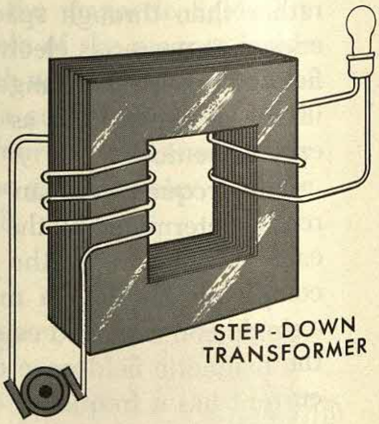
The operation of a transformer can be explained by applying the model on page 223 in the following manner. Assuming an electric current to be a movement of electrons inside a conductor, you know from observation that a current-carrying wire



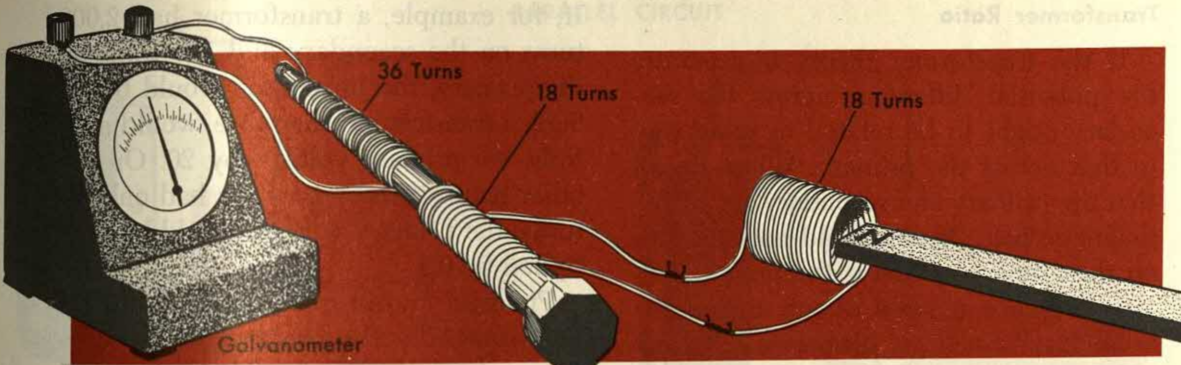
SIMPLE TRANSFORMER



STEP-UP TRANSFORMER



STEP-DOWN TRANSFORMER



has a magnetic field around it. Therefore, an electric current in the ***primary coil*** of a transformer should produce a magnetic field around itself. The primary coil is the coil that is connected to the source of electricity. The iron core inside the primary should, therefore, become a magnet. Observation shows this to be so. A magnet produced as the result of an electric current is called an ***electromagnet.*** An electromagnet loses most of its magnetism when the current stops.

The magnetic field of the primary coil spreads through the entire iron core. The ***secondary coil,*** through which the core also passes, lies in the magnetic field of the primary. The secondary coil is the one connected to the lamp, or other device, which is using the current. The primary and secondary coils are linked by a common magnetic field.

The field is related to the current in the primary coil at any instant of time. Its direction depends upon the direction in which the electrons move, and its strength depends upon the number of electrons moving. Since there is AC in the primary, the direction the electrons move is assumed to be reversing at a regular rate. The magnetic field, therefore, should reverse at the same rate. As the magnetic field changes, it sweeps back and forth across the secondary. The crossing results from a moving magnetic field and stationary wires rather than from the moving wires and stationary field in a generator. But the outcome ought to be the same. A potential difference should appear between the ends of the secondary coil.

Wind an eighteen-turn and a thirty-six-turn coil of insulated wire around an iron bolt, as shown in the diagram. Connect the thirty-six-turn coil to a galvanometer. Form a second eighteen-turn coil of insulated wire just large enough to move easily over the pole of a strong magnet. Connect the ends of this coil to the ends of the eighteen-turn coil on the bolt. Slide the coil back and forth over the magnet pole while observing the pointer of the galvanometer. Is there evidence of current in the thirty-six-turn coil? Apply the transformer theory to explain.

Transformer Ratio

If the transformer theory is accurate, the potential difference across the secondary ought to be related in some way to that across the primary. Why? Recall that the primary and secondary are in one magnetic field. If so, should not one turn on the primary coil have the same potential difference across it as one turn on the secondary? Such an idea seems reasonable, provided there is no loss of field strength between primary and secondary. Scientists believe that in an ideal transformer, which would be one with no losses, such would be the case. The voltage change would thus depend upon the ratio of the turns of the primary and the secondary. That is,

$$\text{voltage change} = \frac{\text{turns of secondary}}{\text{turns of primary}}$$

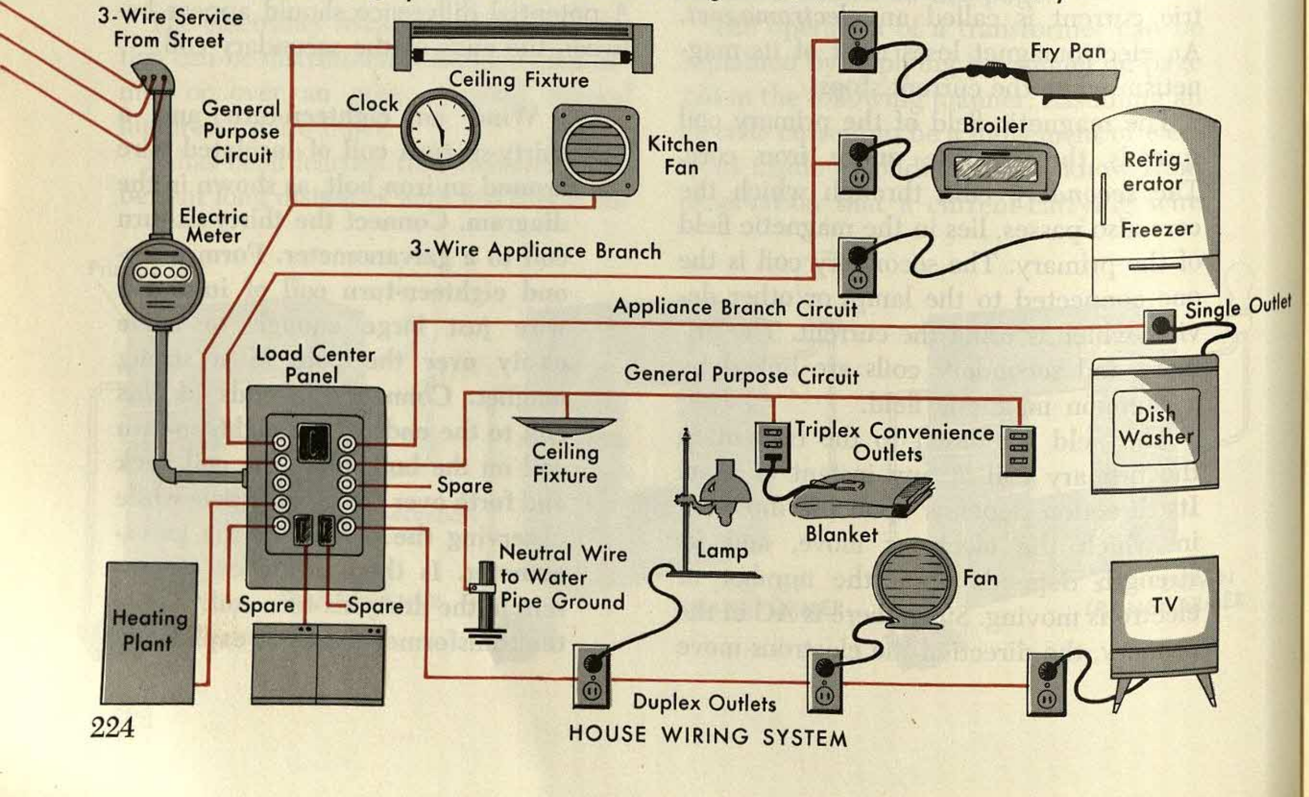
If, for example, a transformer had 2,000 turns on the secondary and 100 turns on the primary, the turns ratio would be 20. Such a transformer, therefore, would multiply the primary voltage by 20. On the other hand, if the secondary had only 20 turns, the primary voltage would be multiplied by 0.2.

Practical transformers do not change the voltage by the exact turns ratio because of losses of energy for one reason or another. However, the losses can be accounted for so closely that scientists believe an ideal transformer would work as the theory indicates.

HOUSE WIRING

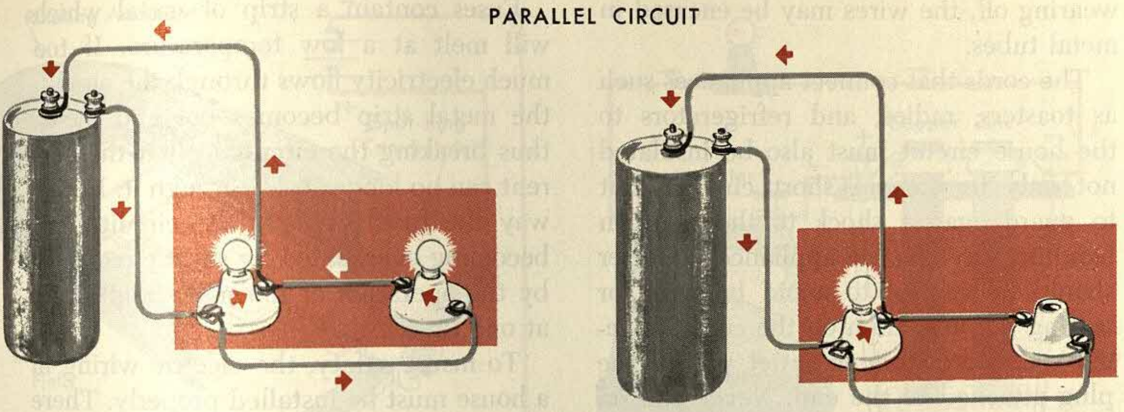
A typical distribution system for a house is shown below.

In a modern house-wiring system, current travels through three lines enclosed in heavy B-X cable.



HOUSE WIRING SYSTEM

PARALLEL CIRCUIT



Electric circuits can be wired either in ***series*** or in ***parallel.*** See the diagrams above and below.

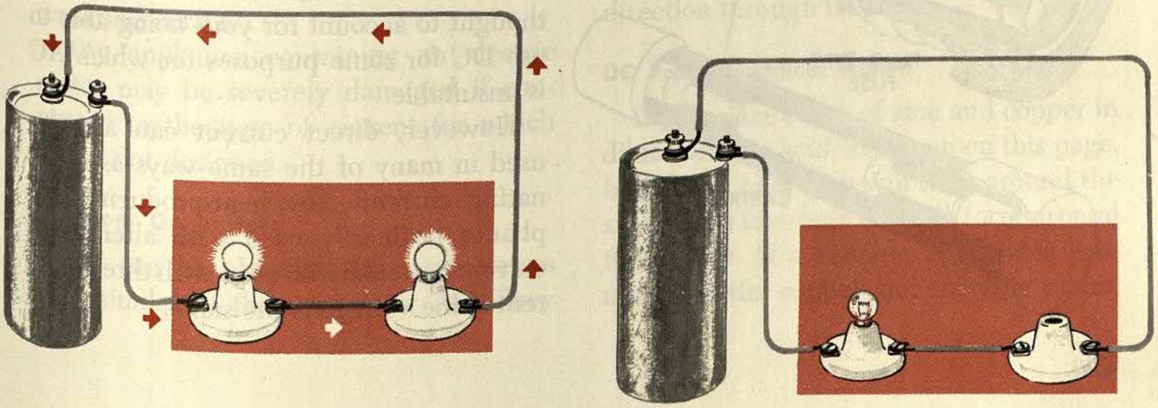
Series and Parallel Circuits

As you can see in the diagram below, left, all the electricity in a series circuit must flow through each lamp. Therefore, if the filament in one lamp breaks, the electricity can no longer continue through the circuit. This is true of all circuits wired in series. It is clear that such wiring would be unsatisfactory for a house because, if one electric device were turned off, the circuit would be broken and none of the other appliances on the circuit would be able to operate. Houses are, therefore, wired in parallel circuits.

In parallel circuits, only the electricity required to operate a particular appliance reaches it. Each appliance can, therefore, be switched off or on without affecting the operation of any other one.

Safety Features in House Wiring

When a circuit carries too much electricity, the wires may become hot enough to cause a fire. If the two wires making up a circuit touch each other, there is so much current in the circuit that it becomes overheated. Such a condition is called a ***short circuit.*** Short circuits in a house wiring system are prevented by use of wires covered with some insulator such as rubber, which does not conduct electricity. To prevent the insulation from

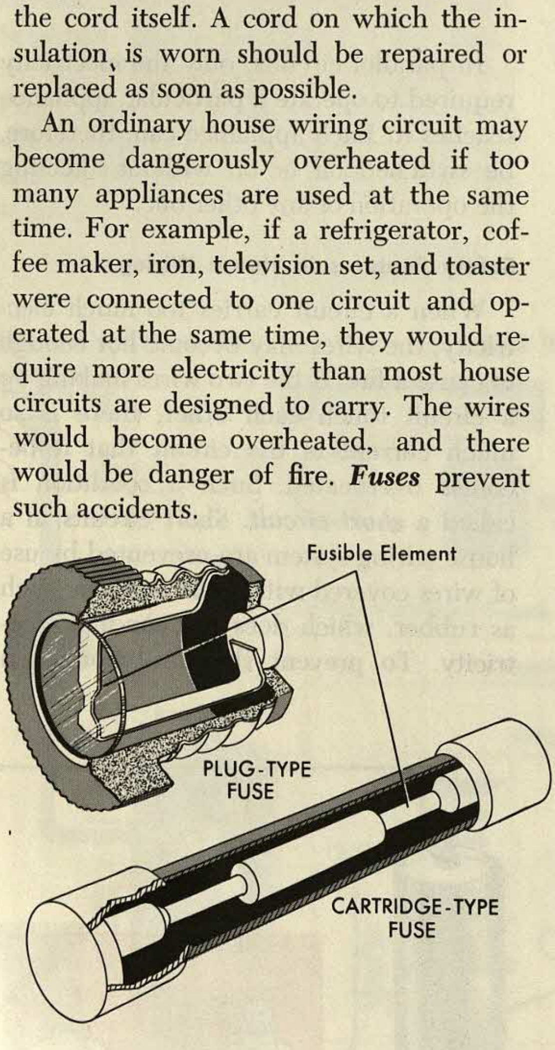


SERIES CIRCUIT

wearing off, the wires may be encased in metal tubes.

The cords that connect appliances such as toasters, radios, and refrigerators to the house circuit must also be insulated not only to prevent short circuits, but to guard against shock to the user. In handling any electric appliance, the user should be careful to avoid breaking or tearing the insulation on the cord. To remove the cord from an outlet, pull on the plug attached to the end. Never pull on the cord itself. A cord on which the insulation is worn should be repaired or replaced as soon as possible.

An ordinary house wiring circuit may become dangerously overheated if too many appliances are used at the same time. For example, if a refrigerator, coffee maker, iron, television set, and toaster were connected to one circuit and operated at the same time, they would require more electricity than most house circuits are designed to carry. The wires would become overheated, and there would be danger of fire. ***Fuses*** prevent such accidents.



Fuses contain a strip of metal which will melt at a low temperature. If too much electricity flows through the circuit, the metal strip becomes hot and melts, thus breaking the circuit so that the current can no longer pass through it. In this way the fuse prevents the circuit from becoming overheated by short circuits, or by the operation of too many appliances at one time.

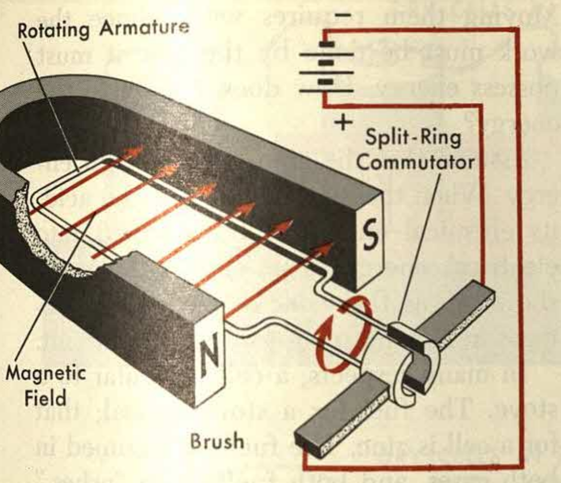
To insure safety, the electric wiring in a house must be installed properly. There should be enough circuits of large enough wire to keep heat losses low in order to operate properly all the electric appliances that are likely to be used.

Rules for safe wiring, prepared by the National Board of Fire Underwriters, are called the National Electric Code. This code should be followed in wiring homes. All electric wiring should, therefore, be done by competent electricians. Most cities require that the wiring systems of new houses be inspected before the dwellings can be occupied.

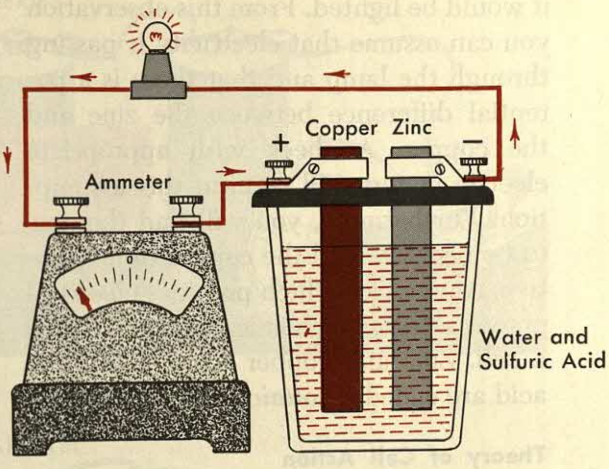
DC ELECTRICITY

DC, like AC, is thought to be conduction electrons in motion. But in DC, the electrons are assumed to move in only one direction. This fundamental difference is thought to account for your being able to use DC for some purposes for which AC is unsuitable.

However, direct current can also be used in many of the same ways as alternating current. Any heat-producing appliance ordinarily used with alternating current can safely be used with direct current if the voltage is the same.



DC ELECTRIC MOTOR



VOLTAIC CELL

Appliances operated by electric motors, however, must have a motor designed especially for the kind of current to be used. The starter in an automobile, for example, is an electric motor designed to be used with direct current from a storage battery. It cannot, therefore, be used with alternating current. Electric clocks, on the other hand, because their motors are constructed for use with alternating current, cannot be used with direct current. Electric clocks in automobiles are designed to operate with direct current. Some radio sets are made to operate with either direct or alternating current, whereas others can operate only with alternating current.

Any appliance containing an electric motor may be severely damaged if connected to the type of current for which it was not designed.

DC From Generators

DC can be obtained from generators very similar to those used for AC. They develop an electrical potential in exactly the same way. The current is taken from such generators through ***brushes*** resting on a device called a ***commutator.*** A brush is a carbon or copper device for conducting current to, or from, a rotating part. A commutator is a device on the armature to reverse the direction of the current.

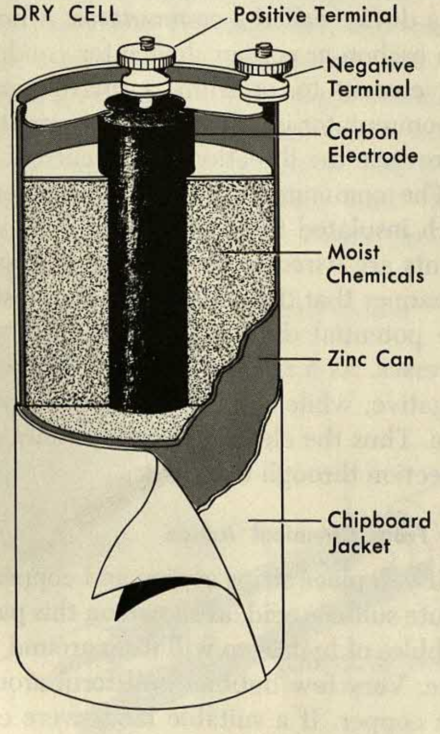
The commutator is built in segments, each insulated from each other. The segments are wired to the field coils in such a manner that they reverse brushes just as the potential difference in the field coil reverses. As a result, one brush is always negative, while the other is always positive. Thus the electrons move in only one direction through the load.

DC From Chemical Action

If you place strips of zinc and copper in dilute sulfuric acid, as shown on this page, bubbles of hydrogen will form around the zinc. Very few bubbles will form around the copper. If a suitable lamp were connected to the copper and the zinc plates, it would be lighted. From this observation you can assume that electricity is passing through the lamp and that there is a potential difference between the zinc and the copper. A check with appropriate electric meters will confirm this assumption. Furthermore, you will find the zinc to be negative and the copper to be positive. Any device which provides electrical potential through chemical action is called a ***cell.*** Zinc and copper strips in sulfuric acid are called a ***voltaic*** (vol-TAY-ik) cell.

Theory of Cell Action

If the model of electricity is accurate, there must be conduction electrons moving through the wire when the lamp lights.



Moving them requires work. Since the work must be done by the cell, it must possess energy. How does it provide the energy?

Assume that the zinc has chemical energy. When the zinc reacts with the acid, its chemical energy is transformed into electrical energy. The electrical energy shows up as the work done on the electrons in moving them through the circuit.

In many respects, a cell is similar to a stove. The fuel for a stove is coal; that for a cell is zinc. The fuel is consumed in both cases, and both fuels leave "ashes." When coal is consumed, heat energy is liberated. When zinc is consumed, electrical energy is liberated. In both cases, the fuel has undergone a chemical change with a loss of potential energy. The energy that fuel loses when it is used appears in another form.

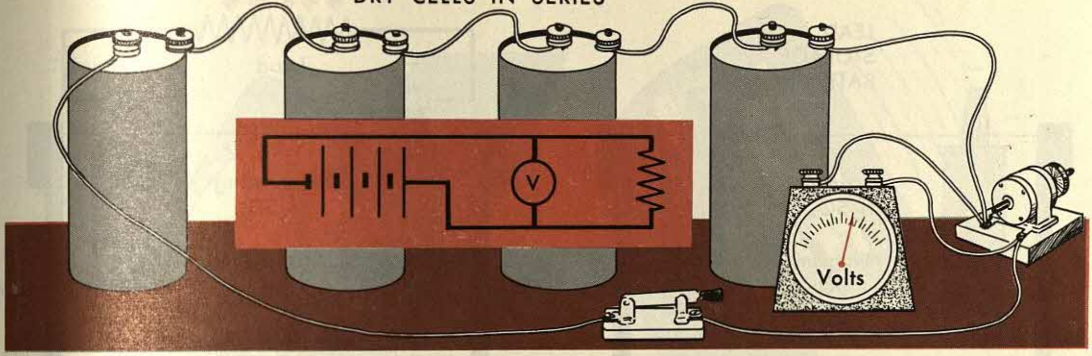
The Dry Cell

The construction of a dry cell is shown on this page. Dry cells are made in several sizes and shapes for use in portable radios, flashlights, electric toys, and in some gasoline engines.

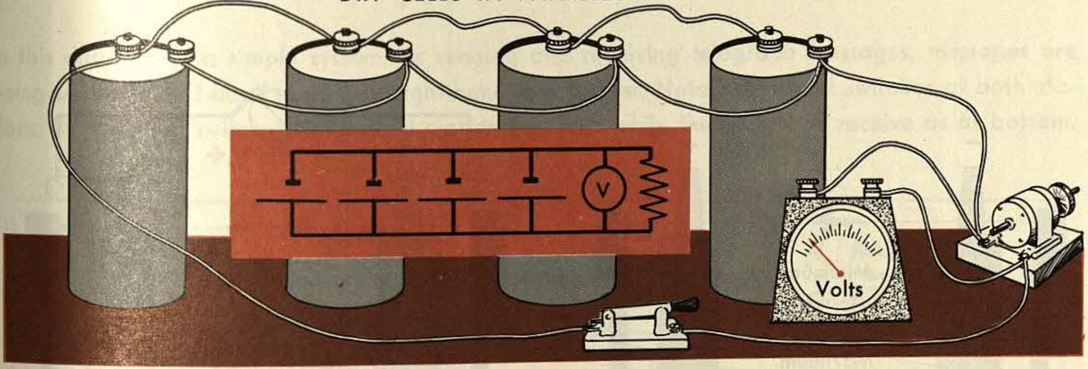
Regardless of size or shape, a dry cell of this type always produces an electromotive force of about 1.5 volts. If more than 1.5 volts is needed, several cells are wired together in series, as shown on page 229. Such a group of cells is called a ***battery.*** The total voltage of such a battery is found by multiplying 1.5 by the number of cells. For example, if the cells in a three-cell flashlight are connected in series, the total voltage is 4.5 volts.

Dry cells are sometimes connected in parallel, as shown on page 229. The volt-

DRY CELLS IN SERIES



DRY CELLS IN PARALLEL



age of a battery of cells so connected is the same as that of a single cell.

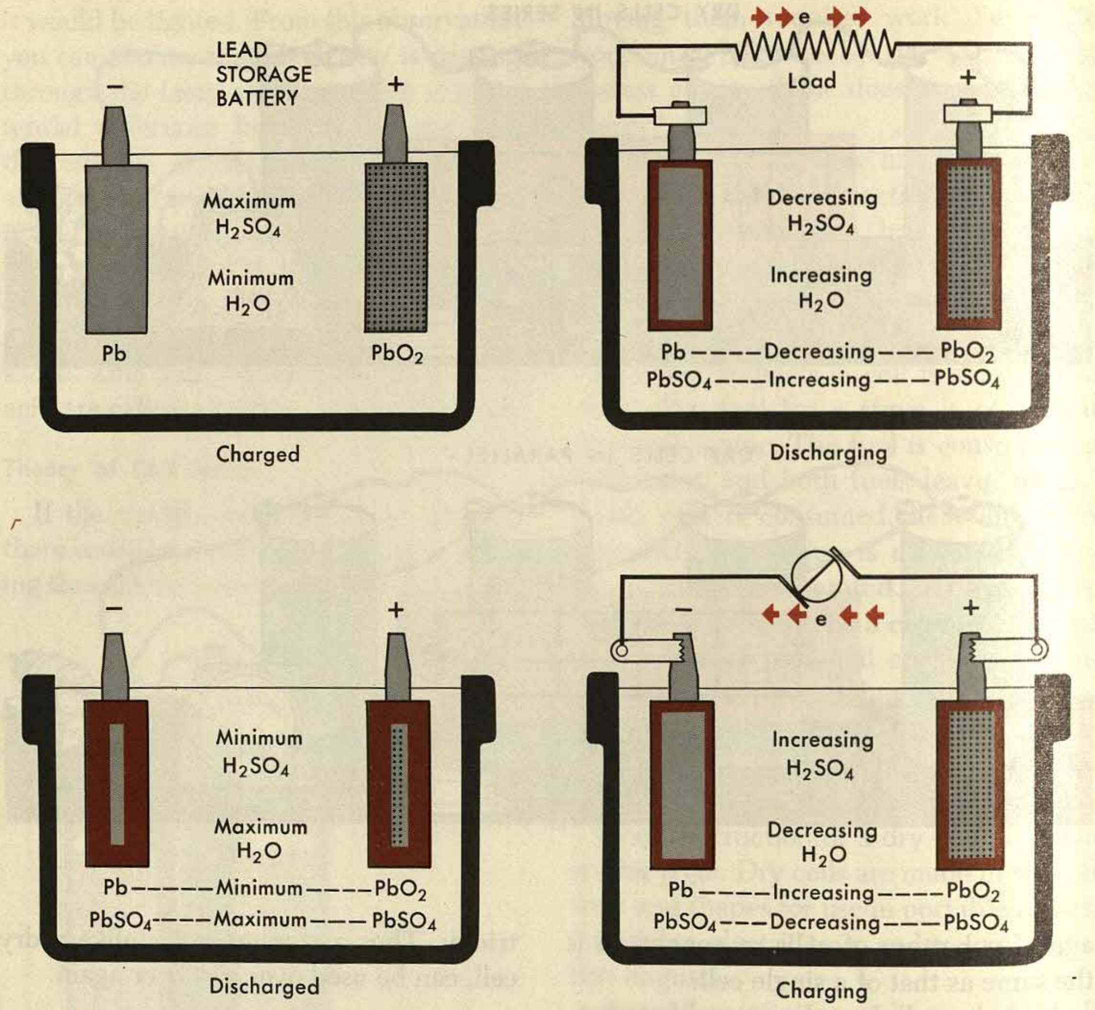
After dry cells have been used for sometime, the chemical change is completed. Then the cells no longer produce an electromotive force and are useless.

Storage Cells

There is a cell, the ***storage cell,*** that can be renewed after it has ceased to furnish electricity. One type of storage cell consists of two lead plates in dilute sulfuric acid. It works as shown on page 230. It can be ***recharged*** by being connected for a time with a source of direct-current electricity. Thus a storage cell, unlike a dry cell, can be used over and over again.

Storage Batteries

The storage battery commonly used in automobiles is known as a ***lead-acid*** battery because the cells are lead plates covered with sulfuric acid. Each cell develops about 2 volts, and there are either 3 or 6 cells connected in series. Batteries are often rated in ***ampere***-hours. An ampere is a unit which measures the number of electrons flowing through a conductor. An 80 ampere-hour battery will furnish about 1 ampere for 80 hours.



The diagrams above illustrate the chemical changes which occur in a lead-acid storage battery cell during its charging and use.

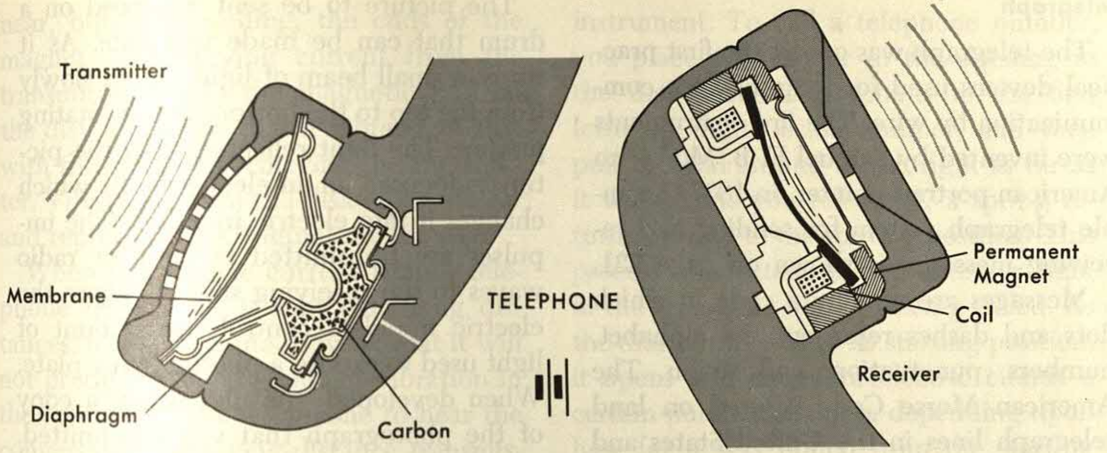
Lead acid batteries should be examined regularly and kept clean. Grease on the terminals helps keep them clean.

When the acid solution drops below the top of the plates, distilled water only should be added.

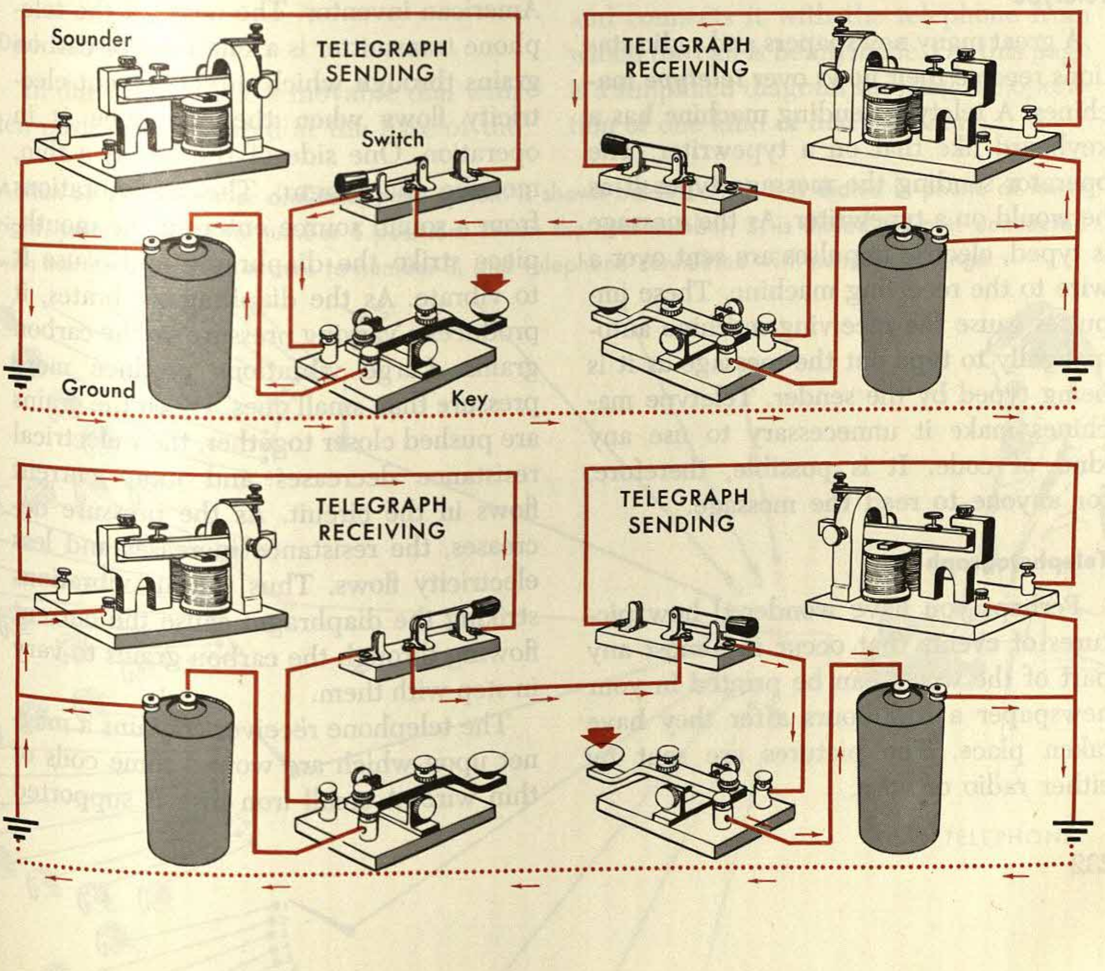
The battery should not be charged too rapidly, nor should it ever be allowed to become fully discharged.

WIRE COMMUNICATION

A number of devices utilizing the rapidity of electric currents for communication have been developed over the years. Some have been discarded, while others are still in use. Among the most widely used are the telegraph, the telephone, and variations of these devices.



In this diagram of a simple system for sending and receiving telegraph messages, messages are being sent from left-hand station to right-hand in top view. Note position of switches at both stations. By reversing switches, right-hand station can send while the other can receive as at bottom.



Telegraph

The telegraph was one of the first practical devices used for long-distance communication by wire. The first instruments were invented by Samuel F. B. Morse, an American portrait painter, in 1837. A simple telegraph system for sending and receiving messages is shown on page 231.

Messages are sent by a code in which dots and dashes represent the alphabet, numbers, punctuation, and so on. The American Morse Code is used on land telegraph lines in the United States and Canada. The International Morse Code is used in most of the other countries of the world. The codes are shown at the bottom of page 158.

Teletype

A great many newspapers and radio stations receive their news over ***teletype*** machines. A teletype sending machine has a keyboard like that on a typewriter. The operator sending the message types it as he would on a typewriter. As the message is typed, electric impulses are sent over a wire to the receiving machine. These impulses cause the receiving machine automatically to type out the message as it is being typed by the sender. Teletype machines make it unnecessary to use any kind of code. It is possible, therefore, for anyone to read the message.

Telephotograph

Perhaps you have wondered how pictures of events that occur in almost any part of the world can be printed in your newspaper a few hours after they have taken place. The pictures are sent by either radio or wire.

The picture to be sent is placed on a drum that can be made to rotate. As it turns, a small beam of light moves slowly from the top to the bottom of the rotating picture. The light reflected from the picture is focused on an electron tube which changes it into electric impulses. The impulses are transmitted by wire or radio waves to the receiving station. There the electric impulses control the amount of light used to expose a photographic plate. When developed, the film shows a copy of the photograph that was transmitted.

Telephone

On March 10, 1876, the first complete sentence was sent over a telephone invented by Alexander Graham Bell, an American inventor. The heart of the telephone transmitter is a small box of carbon grains through which direct-current electricity flows when the telephone is in operation. One side of the box is a thin, metallic diaphragm. The air vibrations from a sound source entering the mouthpiece strike the diaphragm and cause it to vibrate. As the diaphragm vibrates, it produces a varying pressure on the carbon grains. Large vibrations produce more pressure than small ones. When the grains are pushed closer together, their electrical resistance decreases and more current flows in the circuit. As the pressure decreases, the resistance increases and less electricity flows. Thus the air vibrations striking the diaphragm cause the current flowing through the carbon grains to vary in step with them.

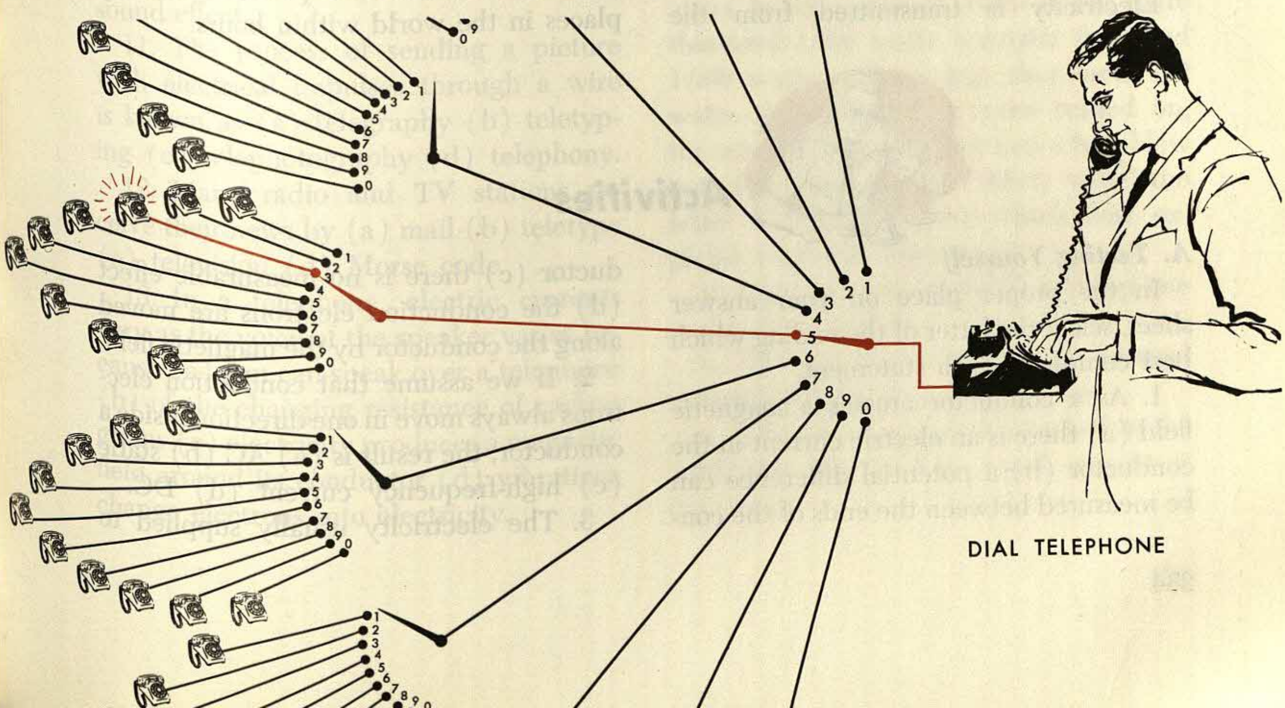
The telephone receiver contains a magnet upon which are wound some coils of thin wire. A small iron disk is supported near, but not touching, the ends of the magnet. The varying current from the transmitter causes the magnetic pull on the disk to vary so that it vibrates in step with the vibrations entering the transmitter. Vibrations from the disk enter the ear and reproduce the original sound.

When the electric current from a telephone transmitter is sent over long distances, it may become so weak that it will not produce a strong enough vibration in the receiver to enable anyone to hear the conversation. For long-distance transmission, these currents are amplified by vacuum tubes or transistors. The use of such amplifiers makes it possible for long-distance telephone calls to be heard as easily as local ones.

Dial Telephones

In dial telephones, a movable dial with ten positions is located at the base of the instrument. To call a telephone number, you place your finger in the opening in the dial which corresponds to the first letter or digit of the number, and then pull the dial around to the right as far as it will go. As you release it, a spring returns the dial to the starting position. This process is repeated for each letter, or digit, in the telephone number being called. As the dial is returned to its starting position, it opens and closes an electric circuit a certain number of times, depending upon how far it was pulled from the starting position. Thus, if 2 is dialed, the circuit may be opened and closed twice; if 5, five times, and so on. These circuit interruptions operate a mechanism at the central office which selects the proper telephone and connects it with the telephone from which the call is being made. On this page is a simplified diagram showing the operation of one kind of dial telephone.

Action of a two-number dial telephone system is shown below. When 5 is dialed in phone at lower right, pointer moves to number 5 position. When the next number, 3, is dialed, pointer connected with number 5 position moves to number 3, and telephone connected with number 53 rings.



SUMMARY

Scientists have developed a model for electricity, which can be used in helping you understand its behavior.

When electrons move through a conductor, such as a copper wire, they become an electric current. If the electrons move in only one direction, the current is direct. If they move back and forth, the current is alternating. Alternating-current electricity can be generated by passing conductors through magnetic fields, or moving magnetic fields past conductors.

Alternating currents have characteristics similar to those of radiant energy. That is, they vary in frequency and amplitude. The frequency of alternating current is determined by the speed at which the armature passes through a magnetic field. The amplitude is determined by the electromotive force, which depends upon the speed of the armature, the number of turns of wire on the armature, and the strength of the magnetic field through which it passes.

Electricity is transmitted from the power station over high-voltage lines to community substations. In the substation, the voltage is reduced, and the electricity is distributed through another system of wires to homes in the locality.

At the homes, the voltage is again reduced and the electricity is distributed to each electric outlet through a system of house wiring circuits. Transformers are used to change the voltage of electricity in the different distribution centers.

In order that house wiring systems may be safe, they should be properly installed. Enough circuits should be provided to supply adequate current to operate lighting fixtures and electric appliances in the home. Fuses protect electric circuits in the home from carrying more current than they are designed to carry safely.

The development of the telegraph made possible long-distance rapid communication over wires. The magnetic effect of coils of wire carrying electricity is used to operate the telegraph.

The development of telephotography permits transmission of pictures to many places in the world within hours.

Activities

A. Testing Yourself

In the proper place on your answer sheet, select the letter of the ending which best completes each statement.

1. As a conductor crosses a magnetic field (a) there is an electric current in the conductor (b) a potential difference can be measured between the ends of the conductor (c) there is no measurable effect (d) the conduction electrons are moved along the conductor by the magnetic field.

2. If we assume that conduction electrons always move in one direction inside a conductor, the result is (a) AC (b) static (c) high-frequency current (d) DC.

3. The electricity usually supplied to

houses is known as (a) static (b) DC (c) AC (d) high-frequency current.

4. An electric generator (a) has four main parts (b) transforms energy (c) produces energy (d) has a commutator.

5. AC seems to (a) resemble radiant energy (b) travel faster than radiant energy (c) act like a fluid (d) lack the wave characteristics of radiant energy.

6. An ideal transformer (a) has a separate field for the primary and secondary (b) can deliver DC from its secondary (c) changes potential difference according to its turns ratio (d) has been made.

7. House wiring circuits are (a) series circuits (b) short circuits (c) parallel circuits (d) open circuits.

8. The device which protects house wiring against overloads is a (a) transformer (b) fuse (c) meter (d) generator.

9. You would find a commutator on (a) a transformer (b) an AC generator (c) a DC generator (d) a fuse.

10. Electricity operates a telegraph sounder because of its (a) magnetic effect (b) heating effect (c) chemical effect (d) sound effect.

11. The process of sending a picture with electrical impulses through a wire is known as (a) telegraphy (b) teletyping (c) telephotography (d) telephony.

12. Many radio and TV stations receive their news by (a) mail (b) teletype (c) television (d) Morse code.

13. In a telephone, electric currents vary as the voice of the speaker varies because (a) you can speak over a telephone (b) of the changing resistance of carbon grains (c) electricity produces a magnetic field around its conductor (d) vibrations change electrons into electricity.

B. Applying Your Knowledge

1. One day a class of high-school students visited a large electric power plant. They noticed that both armature and field of the large AC generator contained a number of electromagnets. There were no permanent magnets in either the armature or the field. A few feet away was a small DC generator wired to the AC generator. The attendant told the students that the DC generator was called an "exciter."

On your answer sheet, write the letter of the statement which would best explain the purpose of the DC "exciter."

a. Uses the additional electricity available when only a few people in the city are using electric power.

b. Turns the AC generator.

c. Produces electricity for the field magnets of the AC generator so that they can produce a strong magnetic field through which the armature can pass.

d. Produces the additional electricity needed when a large amount of electric power is being used in the city.

2. Bill's mother attached three appliances to an extension cord—a hot plate that used 1,800 watts, a roaster that used 1,000 watts, and an iron that used 800 watts. Soon after they were turned on, the cord became very hot and a fuse blew out. On your answer sheet, write the letter of the statement which best explains why this happened.

a. The cord was probably a cheap one and poorly insulated.

b. The cord should have been covered with something other than rubber.

c. The three appliances attached to the extension cord used too much current at one time.

Electric Crane Control & Mfg. Co.

Electromagnets, such as the one shown above, are used at mills to lift heavy loads of iron and steel.

PROBLEM 2: HOW IS WORK OBTAINED FROM AN ELECTRIC CURRENT?

Electricity is assumed to be a form of energy. If this is so, it should be capable of doing work. Experience shows that you can use electricity to do work. Such experience provides strong evidence that the assumption is accurate.

HEAT FROM ELECTRICITY

To explain how heat results from an electric current, the behavior of conduction electrons must be carefully defined. They seemingly cannot move freely through a conductor except in one special case. If a conductor is cooled to absolute zero (−273°C), it is assumed that the electrons can move through it with complete freedom. But at ordinary temperatures, this is not the case. What explanation can be offered, based upon the model of electric conductors that you studied in Problem 1 of this unit?

Moving electrons probably bump into each other. They perhaps collide with the ions other electrons have left behind. Thus, some of the electron energy results in increased electron and atom vibration. The increased vibration can be detected as an increase in temperature. From this it is inferred that heat has been increased inside the conductor.

Connect a 2-foot length of thin copper wire, about #30, in series, with a dry cell and a knife switch. Close the switch. What do you see?

The atoms may be set in violent enough vibration by the moving electrons to destroy the pattern of microcrystals. Then the conductor melts.

Resistance

Electron movement is hindered more in some conductors than in others. In fact, careful studies lead scientists to believe that the hindrance electrons meet at any temperature depends upon the atomic structure of the conductor. For a particular material, say, copper, the length of the conductor and its cross-sectional area also affect the ease with which electrons can move. The hindrance to movement of electrons through a conductor is called ***resistance.***

Resistance is calculated in a unit called ***ohm*.** The resistance of several wire conductors, each one foot long and one-thousandth of an inch (one mil) in diameter, is given below:

RESISTANCE OF METALS

Metals	*Ohms*
silver	9.9
copper	10.4
aluminum	17.0
tungsten	35.8
zinc	36.7
iron, commercial	72.8
nichrome	660.0

You might expect to find some relation between resistance and electric current in a conductor. Such a relation does exist and is known as ***Ohm's Law.*** It will be studied in the next problem.

Heat-Producing Appliances

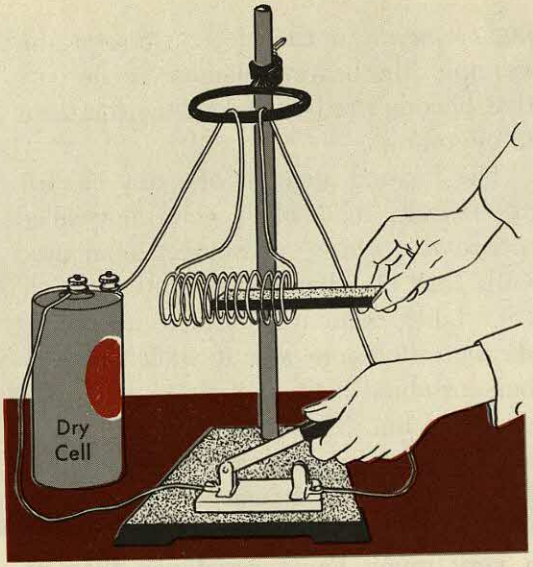
Many electric appliances are designed to produce heat for various purposes. Each of these appliances contains a ***heating element.*** In the electric toaster, for example, the heating element is the wire that becomes red hot when the toaster is in operation.

The heating element of many electric appliances is made of a special alloy called ***nichrome,*** whose resistance, compared with that of other metals, is very high. (See table, column 1.) Electrons moving through nichrome wire in sufficient numbers produce heat enough to make the wire red hot. The cord connecting such an appliance to the electric outlet does not become hot, however, because the wire in it is made of copper. Copper has a very much lower resistance than nichrome. Thus, the amount of current which causes the nichrome to become extremely hot produces only a small amount of heat in the copper wire.

MAGNETISM FROM ELECTRICITY

You know, of course, that a conductor carrying electricity has a magnetic field around it. What you may not realize is that the magnetic field represents energy. The statement is explained below.

It is assumed that every electron (negative charge) possesses a magnetic field when it is moving. In a conductor without a potential difference applied to it, there is, of course, no current and these fields are not observable. But when electrons are pushed along in making an electric current, an observable magnetic field results. Some of the energy used to move the electrons is transformed into work stored in the new magnetic field. The magnetic field represents energy. It should, therefore, have the ability to do work.



If the magnetic field associated with an electric current can do work, you should be able to make it exert enough force to move something. You can check this theory.

Connect a coil of several turns of insulated wire in series with a dry cell and a knife switch. Suspend the coil so that it is free to swing back and forth. Hold one pole of a magnet inside the coil near its center. Close the switch. What does the coil do? Try it with the other magnet pole.

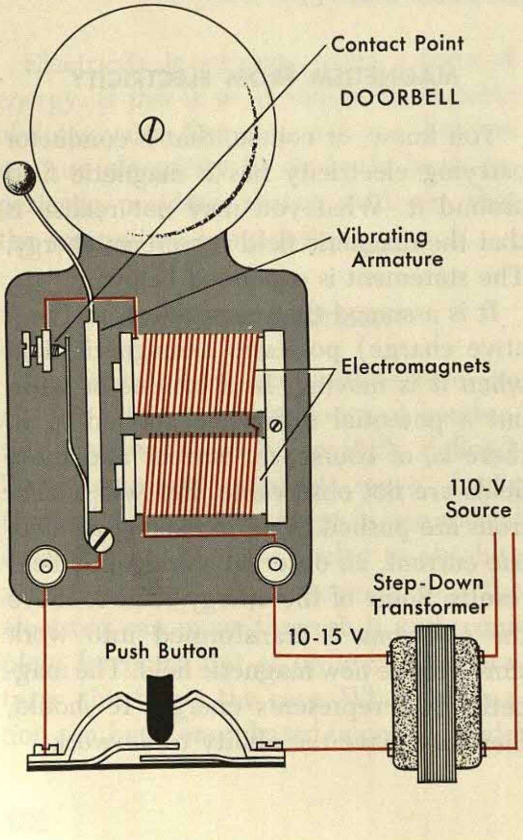
From the movement of the above coil, you can infer that a force acted upon it and that the force was derived from the magnetic field of the current-carrying conductor. The field, therefore, must represent potential energy.

Electromagnets

Electromagnets make the energy of magnetic fields available for use.

One of the simplest devices operated by an electromagnet is the doorbell. The ordinary doorbell is made to operate on from 10 to 15 volts. Since the electricity entering the house is generally 110 volts, it is reduced to the required voltage by a small step-down transformer. Its operation is shown in the diagram on this page.

Electromagnets are also used to operate electric motors. In construction, an electric motor is similar to an AC generator. Like the generator, it has a magnetic field and an armature. The field consists of a number of electromagnets and does not move. The armature rotates.



Types of Armatures

Two types of armatures are used. In one type, a number of coils of wire are wound around the core. In the other type, many short pieces of a good conductor, such as copper, run lengthwise on a core shaped like a cylinder. When electricity passes through the motor, the coils on one type and the copper strips on the other become strong electromagnets.

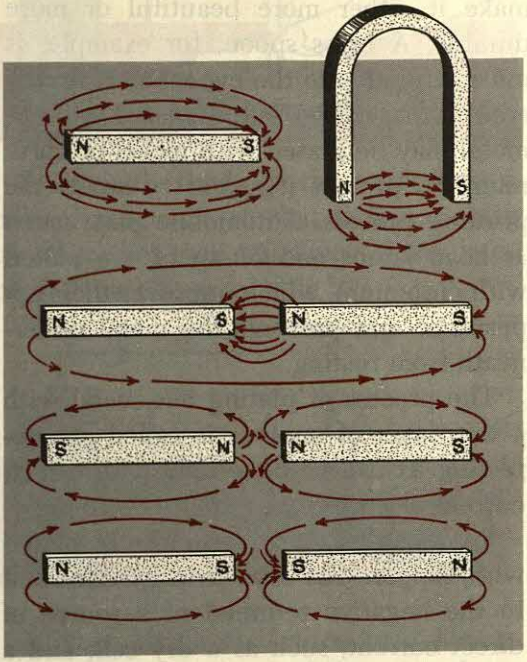
As you will recall, magnets have an N pole and an S pole. The unlike poles attract each other and the like poles repel each other. (See diagram at right.)

In an electric motor, the electromagnets are wired and arranged so that each armature magnet is being pushed and pulled by electromagnets of the field. Thus, an N pole on the armature has an S pole just ahead of it and an N pole just behind it.

Changing Poles

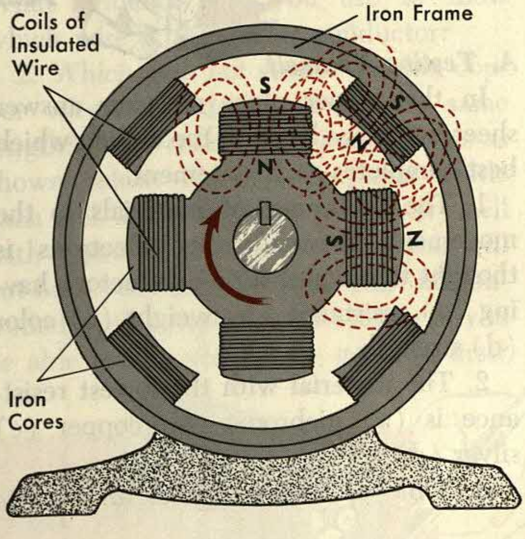
If the poles of the electromagnets on the armature and the field always remained the same, it would not be possible to continue the pushing and pulling effect necessary to keep the armature moving. The poles of the electromagnets on either the armature or the field of an electric motor are constantly being changed as the motor operates. Electric current is sent through the armature or the field so that many magnetic forces are pulling or pushing on the armature to keep it turning.

Electric motors use electricity to run some appliances and oil burners.



The coils in some electric motors are placed so that their magnetic fields push and pull each other, causing the armature to turn. As it turns, the fields are changed, thus providing a steady turning force.

ELECTRIC MOTOR



ELECTROPLATING

It is often desirable to give a metal object a thin coating of another metal to make it either more beautiful or more durable. A brass spoon, for example, is more attractive to the eye when it is covered with silver (silver-plated). Type metal may be plated with nickel or chromium to protect it against wear in the printing process. Automobile parts, such as head lamps and bumpers, are plated with chromium, which improves their appearance and prevents the metal underneath from rusting.

The process of plating one metal with a thin layer of another is called ***electroplating.*** It can be done only with direct-current electricity.

Suppose that a lead strip is to be plated with copper. The lead strip is connected to the negative terminal of a source of direct current, such as a dry cell, and a strip of pure copper is attached to the positive terminal. Both strips are then placed in a solution of copper sulfate and water. Electricity immediately begins to flow through the solution. As it does so, copper is deposited on the lead strip.

Nonconductors can also be coated with metal. For example, a jewelry manufacturer could spray a leaf with a graphite solution to make its surface a conductor of electricity. The leaf could then be electroplated with silver, bronze, or some other attractive metal.

SUMMARY

Energy of an electric current in a conductor is transformed into heat and magnetism. Heat is assumed to result from conduction electrons increasing atomic vibration. Magnetism is assumed to result from energy stored in a magnetic field. Many devices have been constructed to use the energy of heat and magnetism to do work for us.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The hindrance of materials to the movement of conducting electrons is thought to account for a conductor's having (a) resistance (b) weight (c) color (d) strength.

2. The material with the lowest resistance is (a) nichrome (b) copper (c) silver (d) zinc.

3. Some of the energy of an electric current is transformed by a conductor into (a) sound (b) rust (c) fluid (d) heat.

4. To obtain the proper voltage from the house circuit for an ordinary electric bell, it is necessary to use (a) a step-down transformer (b) a step-up transformer (c) a push button (d) an electric generator.

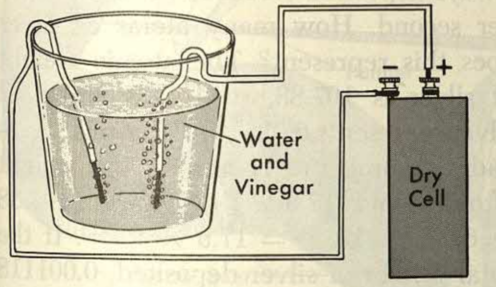
5. Electricity in a conductor makes an electric motor operate because some of its energy is transformed into (a) heat (b) magnetism (c) sound (d) radio waves.

6. An object that is to be electroplated with copper is (a) attached to the positive

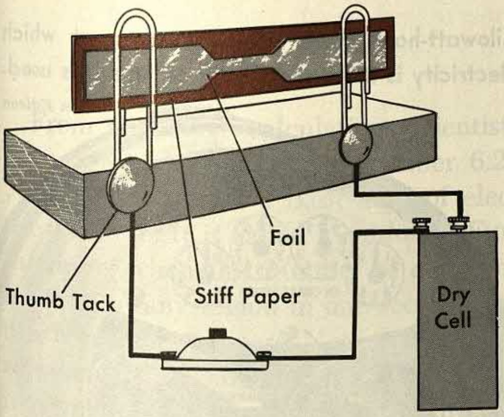
electrode (b) placed in sodium chloride solution (c) connected between the two electrodes (d) attached to the negative electrode.

B. Conducting Demonstrations

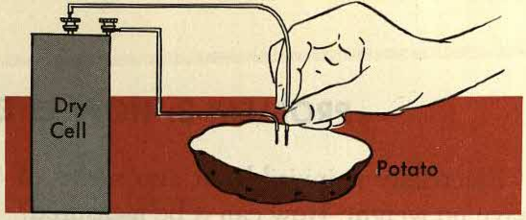
1. Connect wires to a dry cell as shown in the diagram. Put the ends of the wires into a solution of vinegar. Note the gas bubbles that form around the wires. What is happening to the solution?



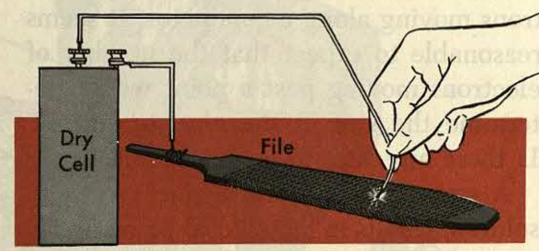
2. Make a fuse by arranging a piece of kitchen foil as shown in the diagram. What happens when you connect the wire to the dry cell? Explain in terms of electrons and copper atoms.



3. Connect two dry cells to a lamp. Connect them first in series and then in parallel. Explain the difference in brightness of lamps.



4. Stick the ends of the wires into a potato, as shown, so that they are close together, but not touching. What happens? How do you explain it?

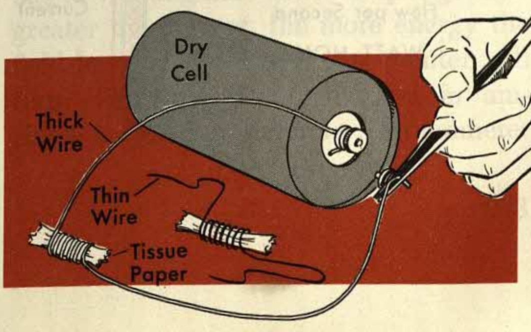


5. Now attach the wires to a file as shown. Move one end of the wire along the file. What causes the sparks?

C. Conducting Experiments

1. Use a dry cell and a small lamp to compare the conductivity of copper wire and iron wire. In order to make this an experiment, what must be controlled? What evidence will you use to show which wire is the better conductor?

2. Which gets hot sooner—a thin copper wire or a thick one of the same length? Make coils with pieces of wire as shown below. Place tissue paper inside each coil. Hold the wire on the dry cell with a pair of tweezers so that you will not burn your fingers. What must be controlled in this experiment? How will you be able to tell which wire gets hot first?



PROBLEM 3: HOW IS ELECTRICITY MEASURED?

Electricity is invisible. It also seems to have no weight. How can it be measured?

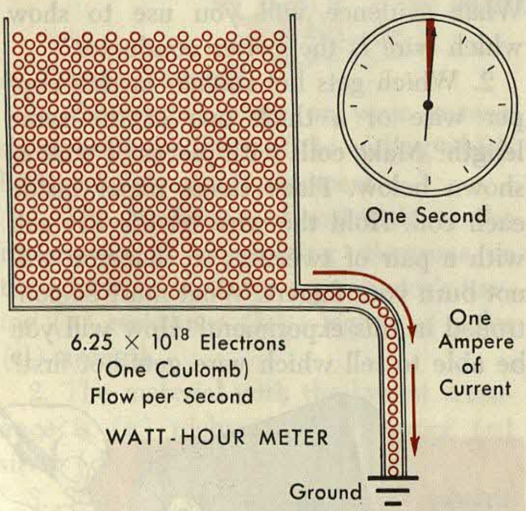
THEORY OF MEASUREMENT

In your model (see page 217), you think of an electric current as consisting of electrons moving along a conductor. It seems reasonable to expect that the number of electrons moving past a point would determine the size of the electric current. Is there any way to count the electrons?

A current in a silver nitrate ($AgNO_3$) solution results in metallic silver being deposited on the negative electrode. Assume that each silver ion (Ag^+) has a positive charge the same size as the negative charge of an electron. Then suppose you measure the amount of silver deposited by a current in a fixed period of time, such as a second. If you know the number of atoms of silver deposited, you will also know the number of electrons, since each atom gains one electron in changing from a silver ion (Ag^+) to a silver atom (Ag^0).

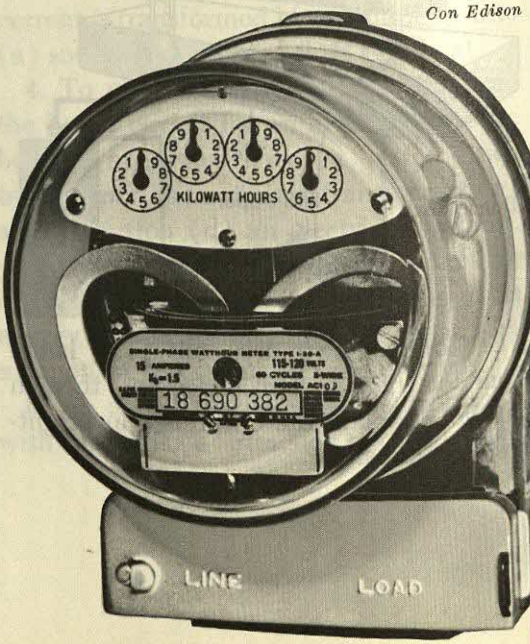
The Coulomb and the Ampere

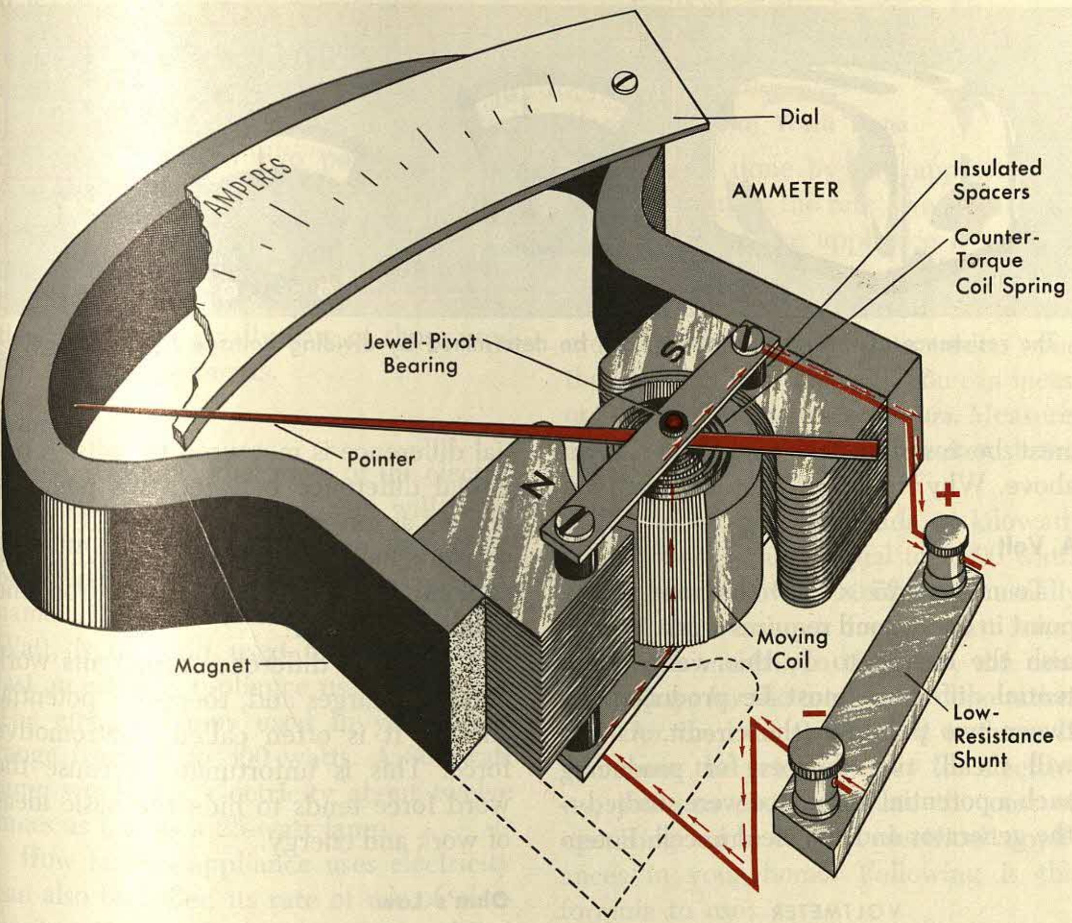
Michael Faraday, a nineteenth-century British physicist, found out by experiment that a certain charge of electricity always deposited 0.001118 grams of silver per second. How many atoms of silver does this represent? The atomic weight of silver is 107.88, so 107.88 grams of silver represents 6.025×10^{23} atoms (Avogadro's number). Therefore, the weight of one atom is 17.9×10^{-23} grams ($107.88 \div 6.025 \times 10^{-23} = 17.9 \times 10^{-23}$. If the total weight of silver deposited, 0.001118 grams, is then divided by the weight of one silver atom, 17.9×10^{-23}, you would get the number of atoms, 6.25×10^{18}. Since each atom took one electron, you have counted the electrons.



Kilowatt-hour meter measures rate at which electricity is used and length of time it is used.

Con Edison



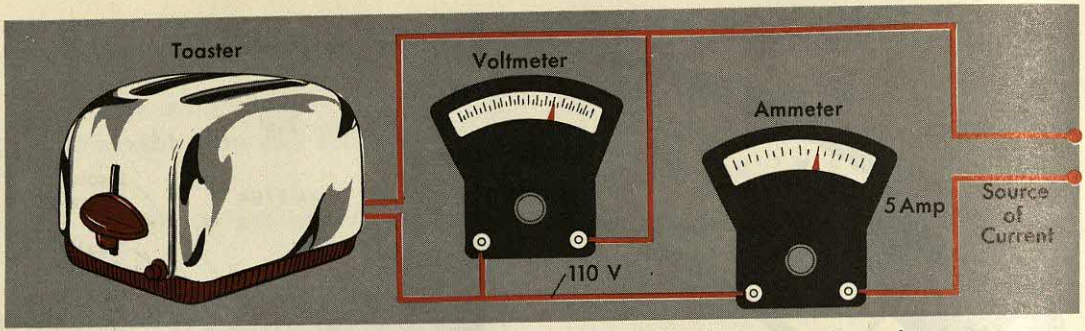


From the above calculations scientists have agreed to accept the number 6.25 × 10^{18} electrons as a basic unit of electrical charge. It is called a ***coulomb.*** Furthermore, when this number of electrons moves past any region in one second, the rate is called an ampere. Note that ampere represents rate, not quantity of electron movement. Quantity is measured in coulombs. In 1908, Congress agreed to accept as a standard for an ampere "that unvarying current which will deposit 0.001118 grams of silver per second."

Measuring Amperes

The most commonly used instruments for measuring amperes and volts utilize the energy of the magnetic field around a conductor that carries an electric charge. See diagrams above and on page 244.

In the first one, the coil is mounted in such a way that the energy of its field has to work against the hair springs. The greater the current, the more energy the field has and the farther the pointer will turn. This instrument, marked in amperes, is called an ***ammeter.*** An ammeter



The resistance of the toaster, above, can be determined by dividing voltage by amperage.

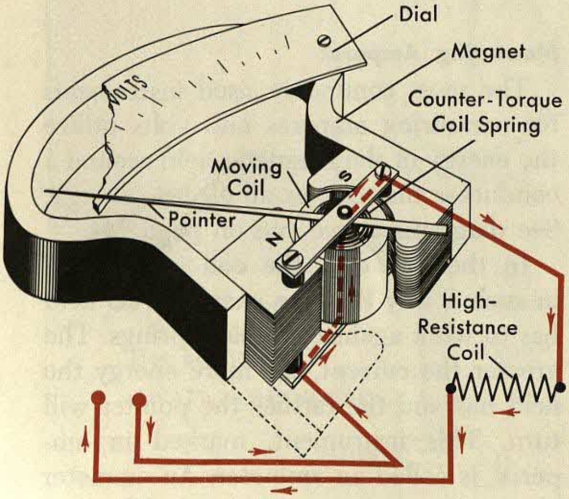
must be inserted in a circuit as shown above. Why?

A Volt

To move 6.25×10^{18} electrons past a point in one second requires work. To furnish the energy to do this work, a potential difference must be produced between two points in the circuit. As you will recall, two devices for producing such a potential difference were studied—the generator and the electric cell. Potential difference is measured in volts. A potential difference between two points is defined as one volt if one joule (10^7 ergs) of work has to be done in moving one coulomb (6.25×10^{18} electrons) from one point to the other.

A potential difference represents work done on charges and, therefore, potential energy. It is often called electromotive force. This is unfortunate, because the word force tends to hide the basic ideas of work and energy.

VOLTMETER



Ohm's Law

Electrical-measurement units are defined so that a potential difference of one volt will move one ampere against a resistance of one ohm. This relationship can be stated in the following formula known as Ohm's Law.

$$R\ (\text{ohms}) = \frac{E\ (\text{volts})}{I\ (\text{amperes})}$$

Ohm's Law is actually a definition of resistance (R). Resistance is the ratio between volts and amperes, both of which can be measured. Ohm's law is used to compute the resistance of the toaster shown above.

Voltmeter

If resistance of the proper size is built into a current-measuring meter, it can also be marked so as to measure potential difference between two points in volts. Such an instrument is known as a ***voltmeter.*** A voltmeter is used as shown on page 244. Some meters depend upon the heating effect of current for their operation. This is especially true of those used for AC measurements.

Watts

If you will examine some of the electric appliances in your home, you will probably find a small plate containing a number followed by the word ***watts.*** The watt, named for the Scottish scientist James Watt, is the unit used to measure how fast an electric appliance uses electricity. The electric lamps used in your home range from 25 to 300 watts. A 300-watt lamp would use electricity about twelve times as fast as a 25-watt lamp.

How fast an appliance uses electricity can also be called its rate of use of electricity. Using electricity means doing work. Therefore, the number of watts shows the rate at which an appliance does work. But rate of work is power. (See Unit 3, page 79.) Thus the watt is a unit of electrical power.

You will recall that a volt is equivalent to 1 joule of work done on 1 coulomb of charge. An ampere is the rate at which a charge moves, i.e., 1 coulomb per second. Scientists combined these two definitions to define a watt—the work done at the rate of 1 joule per second. Electrical watts for DC circuits, and for AC circuits where only resistance is a factor, can be computed with the following formula:

$$\text{Watts (power)} = \text{E (volts)} \times \text{I (amperes)}$$

Measuring Total Work Done

The work done by any appliance depends both upon the rate (watts) and the length of time the appliance is used. It takes more electricity to operate an electric iron for one hour than for thirty minutes. By combining the rate (watts) and the length of time (hours), you can measure the total work in ***watt-hours.*** Measurement is made by a ***watt-hour meter,*** shown on page 242.

The meter actually reads in kilowatt-hours (kwh), a unit equal to 1,000 watts × 1 hour. Power companies usually charge the consumer for kilowatt hours used each month. In this way, the consumer pays for the total work done rather than for the rate at which it is done. If you know the price you pay for electricity, you can easily estimate the cost of operating each of the electrical appliances in your home. Following is the formula to use:

$$\text{cost} = \frac{\text{watts} \times \text{hours} \times \text{cost per kwh}}{1{,}000}$$

SUMMARY

Electricity is measured indirectly by observing its chemical, magnetic, or heating effect. Potential difference is measured in volts, while rate of current is measured in amperes. Resistance of a circuit is ratio of rate of current to potential difference. Its statement is known as Ohm's Law. The rate at which electricity does work is measured in watts. Total work done is usually measured in kilowatt-hours.

Activities

A. Testing Yourself

On the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The charge of electricity that always deposits 0.001118 grams of silver per second is the (a) ampere (b) volt (c) ohm (d) coulomb.

2. If a 100-watt electric lamp is operated for ten hours, work done is represented by (a) 100 watts (b) 1,000 kwh (c) 1 kwh (d) 0.1 kwh.

3. The instrument which measures the rate of current is the (a) ammeter (b) voltmeter (c) watt meter (d) kilowatt-hour meter.

4. If the potential difference across a toaster is 110 volts and the current rate is 5 amperes, the resistance is (a) 550 ohms (b) 0.045 ohms (c) 22 ohms (d) none of these.

5. If the potential difference across an electric range is 220 volts and the current rate is 10 amperes, the power is (a) 2,200 watts (b) 22 watts (c) 2.2 kwh (d) 2,200 kwh.

B. Making Surveys

1. Locate the wheel in your electric meter, which turns about three times per watt, and observe how fast it turns when different appliances are being used. Compare its speed with the wattage rating on the appliances.

2. Make a list of all the electric appliances in your home. After the name of each appliance, tell what electric effect causes it to work.

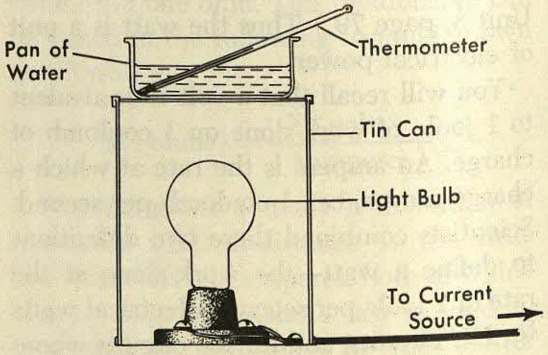
3. Determine the total watts of all lamps in your home. Compute the kilowatt-hours used by the lamps if they were all turned on for three hours.

4. Check the watt ratings of electric irons, toasters, radios, TV, and other electric appliances in your home. How many kilowatt-hours would be used by these appliances if all were used for three hours?

5. The kilowatt-hours used in your home are reported on your monthly electric bill. If you can get these bills for a period of one year, make a graph to show the amounts used each month. Do you note any seasonal differences? If so, what accounts for the differences?

C. Making Comparisons

Plan a way to compare the amount of heat given off by incandescent lamps of different wattage. What could you use to trap the heat so that you could measure it? With what instrument would you measure it? What things would you have to control to be sure your comparisons were fair ones? How could you show your results in a graph?



United States Air Force

An atomic explosion, characterized by a mushroom-shaped cloud, yields vast quantities of heat.

PROBLEM 4: HOW IS HEAT ENERGY OBTAINED?

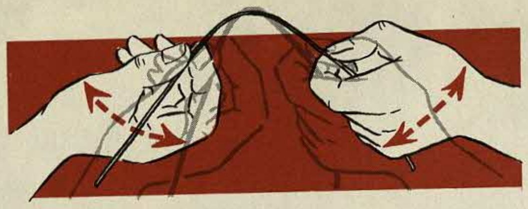
As you remember from Unit 2, scientists believe that most matter of the universe, including that of which man and other living things are composed, is made up of small particles called molecules. Furthermore, these molecules are thought to be in motion constantly. This constant molecular motion is now thought of as heat energy. Molecular motion, or heat, is the energy responsible for many life activities. Heat can also be used to operate machinery.

Since almost everything on the earth contains molecules in motion, almost everything possesses heat energy. However, not all things possess heat energy to the same degree. Thus, both ice and boiling water possess heat energy, but the boiling water has it to a greater degree than the ice. Man can use heat energy for practical purposes when the molecules of a substance change the speed of their motion. Man's basic problem in obtaining heat energy is simply one of increasing, decreasing, or maintaining molecular motion in substances.

THE NATURE OF HEAT ENERGY

If you have ever tried to describe heat energy, you probably have found it very difficult. It is not something you can see, smell, or taste.

For a long time heat energy was believed to be a fluid called ***caloric***, from a Latin word meaning "heat." It was thought that when a warm object was placed near a cold object, some caloric was transferred



from the warm object into the cold object, which was thus warmed.

This idea about heat energy did not explain satisfactorily what happened when some materials became hot. For example, it was noted that when a small iron wire was bent back and forth rapidly, it became hot at the place where it was bent. Certainly no caloric was added to the wire, since there was no hot object next to it. How, then, could the wire become hotter at the bend?

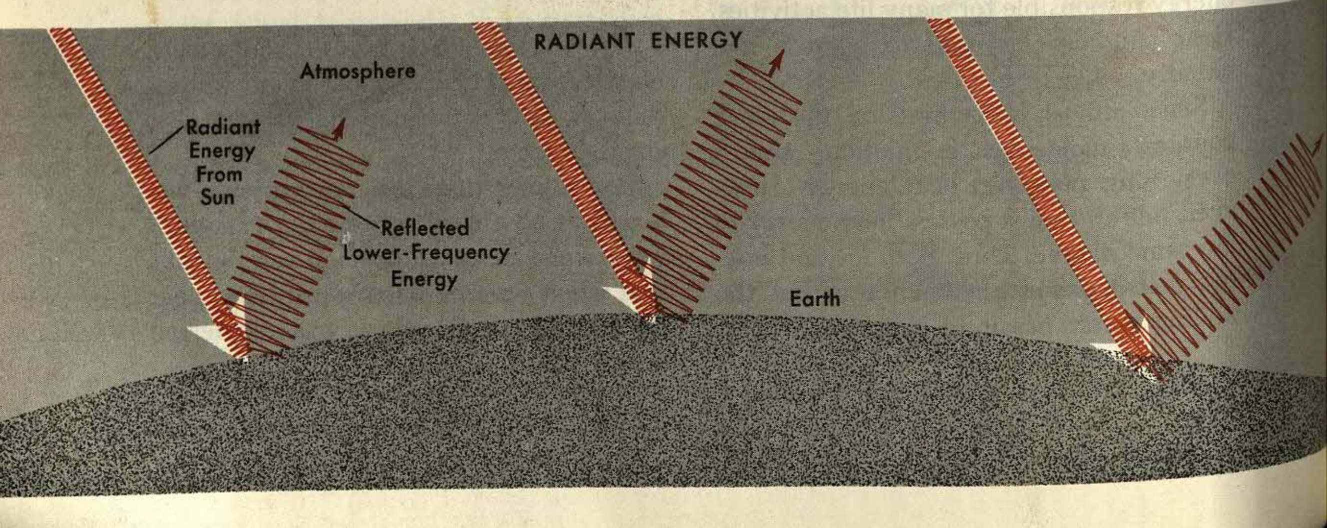
If molecular motion is heat energy, then bending the wire increased the motion of those molecules at the bend. The energy to make them move more violently came from the work done on the wire to bend it. The mechanical work done on the wire became apparent as increased heat.

Much of the language describing heat energy is that used when it was thought to be a substance—caloric. For example, heat is described as moving, flowing, being transferred from a hot object to a cold object, or being carried by convection currents. In all of these expressions, it is easier to think of heat as a thing rather than as motion or kinetic energy. But from observation it is known that, to understand heat, you must think of it as the kinetic energy of the molecules and atoms of any substance.

You must remember to think of heat as energy, not as a substance. One way to check your thinking is to substitute "the ability to do work" for heat, or heat energy, in a sentence. If the sentence still has meaning for you, you are thinking of heat and energy accurately.

How the Sun Warms the Earth

Since most of the 93,000,000 miles between the earth and the sun is space, only radiant energy can reach the earth from the sun. You will recall that it is the rays of infrared radiant energy that produce most of the heating effects of the sun upon the earth. (See page 199.) Although these rays have traveled millions of miles through space, when they reach the earth they have not lost their power to increase the heat energy in the objects they strike.



By increasing the movement of the molecules or atoms of the objects which absorb them, the rays produce sufficient heat energy to make life possible on the earth.

Heat Energy From Chemical Reaction

In Unit 2, you learned that some chemical reactions give off heat energy to their surroundings. Burning of fuels such as wood, coal, and oil produces heat energy.

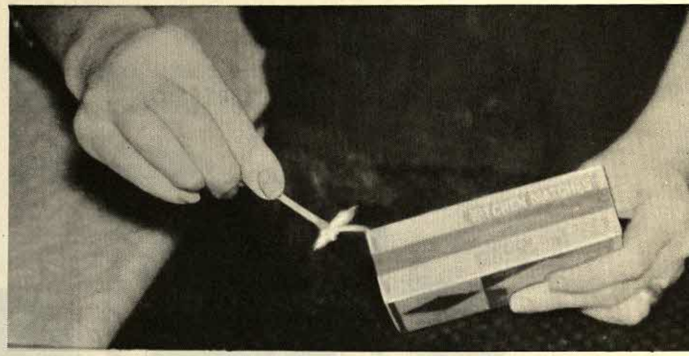
Before a fuel will burn with a flame, its heat must be increased until the substance reaches a temperature called kindling temperature. Each substance has its own kindling temperature.

Heat energy can also be increased by chemical reactions other than combustion. Mixing a solution of concentrated sulfuric acid and water, for instance, may cause a rapid increase in heat—so rapid, in fact, that special care must be taken to prevent accidents when these two substances are mixed. Remember always to pour acid slowly into water. Never pour water into acid, because acid may spatter.

Heat Energy From Electricity

As you learned in this unit, an electric current is the movement of billions of electrons in a conductor. It is thought that the increase in heat energy observed in a conductor carrying electricity results from the increased motion of electrons and atoms. Thus electricity is a source of heat energy.

You have also learned that electricity can be used to produce different types of radiant energy. This radiant energy, in turn increases the heat energy of the material that absorbs it. Hence electricity can indirectly increase heat energy.



Friction creates heat when match is struck.

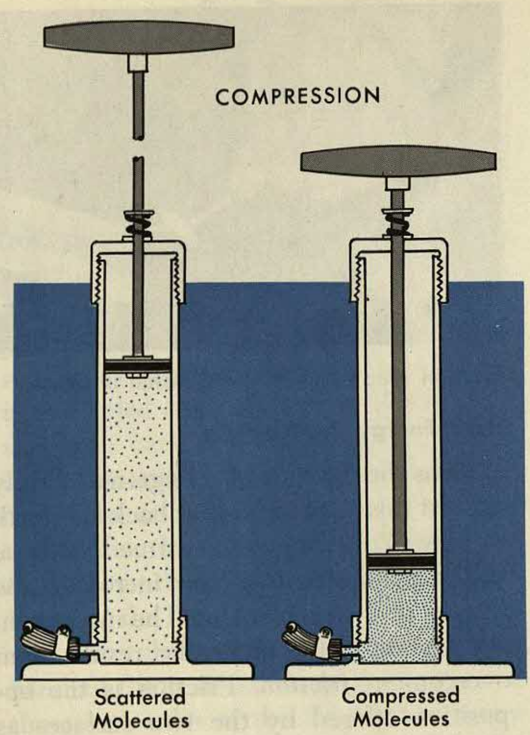
Heat Energy From Friction

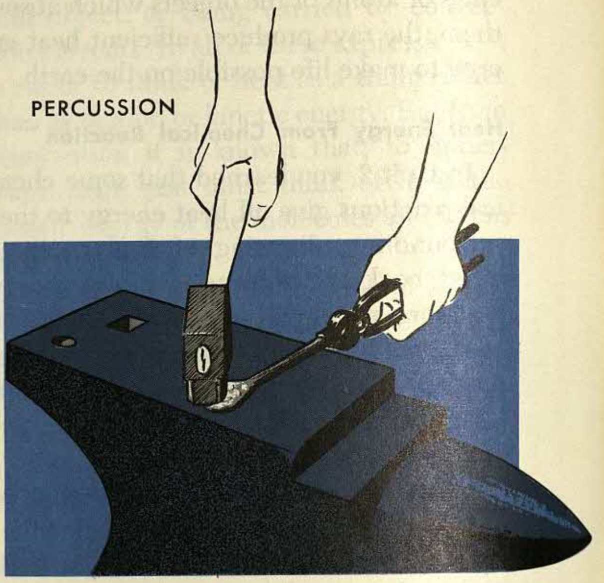
Press the flat part of a fingernail tightly against this page and rub it back and forth rapidly. Your finger is warmed because rubbing objects together increases the motion of their molecules. The increase in the motion of the molecules results from overcoming ***friction.*** Friction is the opposition offered by the two surfaces as they slide over each other.

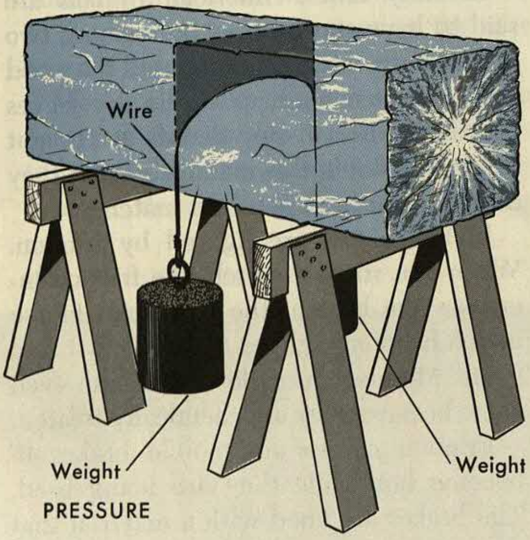
In early times, American Indians are said to have started fires by rubbing two pieces of dry wood together until the wood became hot enough to kindle dry leaves or other material. Boy Scouts are taught to kindle fires in this manner so that they do not have to depend on matches.

Matches, too, are lighted by friction. When you strike a match, the friction increases the heat of the chemicals in the match head enough for them to burst into flame. Matches burn slowly with an even flame because they are chemically treated.

Friction causes automobile brakes to become hot while they are being used. The brakes are lined with a material that does not burn readily. However, if the brakes are not adjusted properly, the linings may burn.







Aigner-Monkmeyer

Ice melts under pressure of skate's blade.

Heat Energy From Other Sources

Have you ever pumped air into a bicycle or automobile tire with a hand pump? You probably noticed that the rubber tube which carries air into the tire becomes warm.

As you force the piston down into the cylinder, the air molecules become crowded, or compressed, and they begin to move more rapidly. This increase in the speed of the air molecules warms the tube. The increase in heat energy obtained is caused by ***compression.***

If you hammer a nail vigorously for a short time, you will find that it becomes hot. The pounding increases the movement of molecules where the nail is being hit. The increased heat energy produced by hammering or pounding is called heat from ***percussion.***

It is also possible to increase heat energy with two types of nuclear reaction—fission and fusion. The fission action can be carried out slowly enough to permit the heat energy to be used to generate electricity and to propel submarines, surface ships, and airplanes. Scientists are also trying to develop ways to control fusion so that it, too, can become a source of heat energy. (See Unit 2, page 65.)

SUMMARY

The heat energy of a substance is increased whenever the movement of its molecules or atoms is increased. The movement of the molecules of a substance can be increased by (1) radiant energy (2) chemical reaction (3) electric currents (4) friction (5) compression (6) percussion (7) fission and (8) fusion. Radiant energy, chemical reactions, and electric currents are the most commonly used means of obtaining heat energy.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each sentence.

1. The one with the lowest kindling temperature is (a) paper (b) coal (c) wood (d) gasoline.

2. Increasing heat energy by rubbing two sticks together is an example of heat energy from (a) percussion (b) friction (c) chemical action (d) static electricity.

3. Heat is thought to be (a) a substance that moves from a hot to a cold object (b) the motion of the atoms or molecules of a substance (c) a substance that moves from a cold to a hot object (d) one of the chemical elements.

4. Increasing heat by burning a fuel is an example of heat energy from (a) percussion (b) electricity (c) chemical action (d) compression.

5. The earth is warmed by the sun because it (a) receives heat from the sun (b) obtains caloric from the sun (c) absorbs radiant energy from the sun (d) is attracted by gravitational force of the sun.

PROBLEM 5: HOW IS HEAT ENERGY MEASURED?

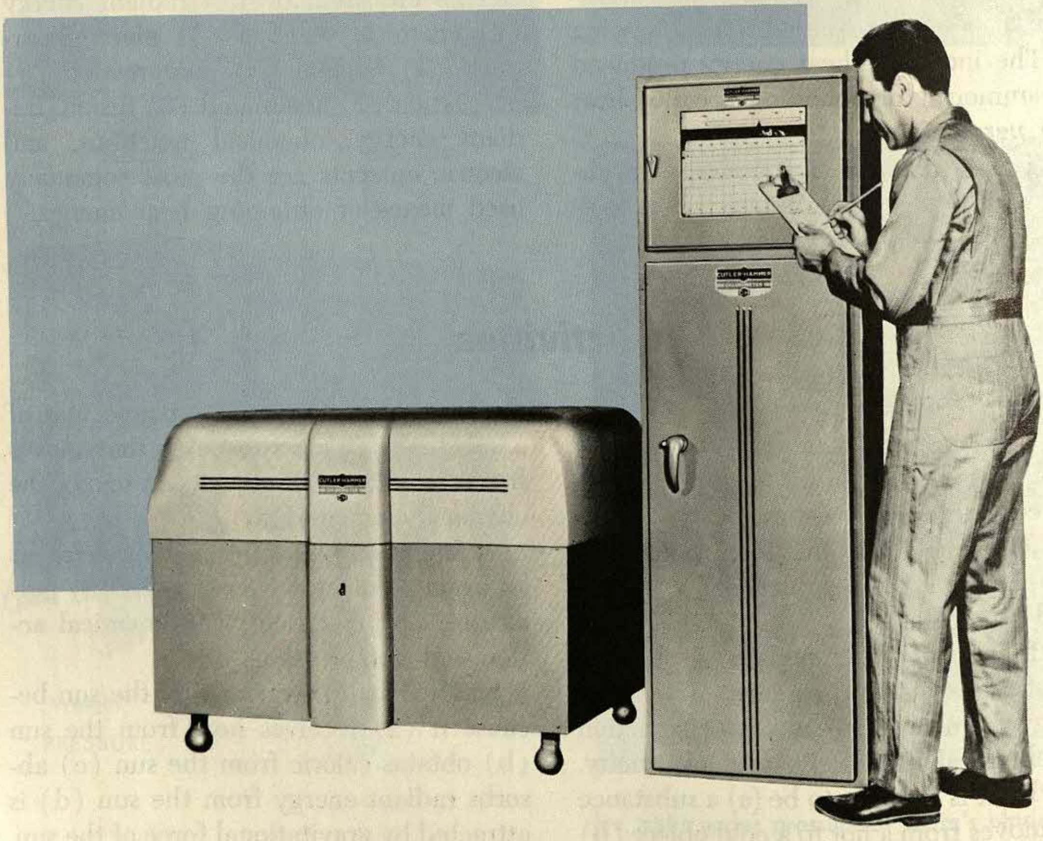
You will recall that most of the materials and forces considered so far were measured in some way. The characteristics of air, for example, were expressed in terms of certain measurements such as volume and weight. Radiant energy was measured in terms of wave length, frequency, and amplitude. Before scientists were able to learn what they know today about electricity, they had to develop many measurements for electric currents. Scientists have also found ways of measuring the sizes and positions of bodies of the universe. And in order to solve problems dealing with heat energy, scientists had to be able to measure heat and its effects on various things.

METHODS OF MEASURING TEMPERATURE

An explanation of the methods of measuring ***temperature*** is understood best in

This electronic calorimeter, used to measure heat calories, maintains a continuous visible record.

Cutler-Hammer—American Gas Assn.



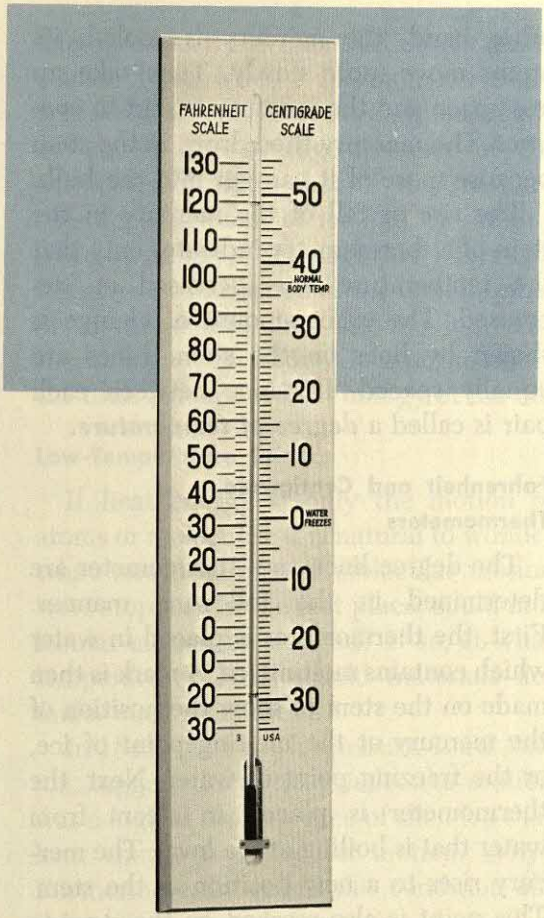
terms of a model. In such a model, temperature is assumed to be the average kinetic energy of the atoms and molecules of a substance. The higher their average kinetic energy, the higher the temperature of the substance.

Kinetic energy depends upon the mass and velocity of the moving molecules. The mass of a particular molecule is assumed to be constant, but it is thought that the increase in kinetic energy is caused by an increase in the velocity of the molecule. According to this, temperature changes and heat energy of a substance are related to the movement of its molecules.

Any increase in the movement of the molecules of a substance should cause the molecules to spread farther apart. If this happens, they should occupy more space, and an increase in volume should be observed. Does such an increase in volume take place when a substance is heated? Experience shows that, for most substances, such an increase actually does occur. Therefore, by measuring the increase in the volume of a substance, you could obtain an indirect measurement of its increase in temperature if the model is accurate. The most common device for measuring temperature is a thermometer. Its measurement is based upon the assumption that the model is accurate.

Construction of a Mercury Thermometer

The photograph on this page shows one kind of thermometer. The bulb at the base of the stem and the stem are made of glass. The bulb is filled with mercury. The thick-walled stem is pierced by a tiny channel which runs from the bulb to the top of the stem, which is sealed.



Taylor Instrument Co.

Mercury thermometer indicates temperature on Fahrenheit and Centigrade scale.

When the bulb of the thermometer is placed in a substance whose temperature you want to know, the mercury inside the bulb soon becomes the same temperature as the substance around it. If the mercury is warmed by the substance, the average velocity of its atoms is increased and they occupy more space; that is, the mercury ***expands.*** Because the channel in the stem is the only place into which the mercury can move, it rises into the stem. If, on the other hand, the mercury is cooled, its atoms move more slowly. They take up less space and the mercury is said to ***contract.*** The mercury then drops in the stem because more of it can get into the bulb.

The rise or fall of the mercury in the stem of a thermometer indicates only that the temperature has increased or decreased. The exact amount of change is shown by lines on the stem. Lines are equally spaced. Distance between each pair is called a ***degree of temperature.***

Fahrenheit and Centigrade Thermometers

The degree lines on a thermometer are determined in the following manner. First, the thermometer is placed in water which contains melting ice. A mark is then made on the stem to show the position of the mercury at the melting point of ice, or the freezing point of water. Next, the thermometer is placed in steam from water that is boiling at sea level. The mercury rises to a new position in the stem. This point is also marked on the stem to indicate the boiling point of water. Distance between these two marks is divided into degrees by equally spaced lines.

For the Fahrenheit thermometer, the mark at the boiling point is labeled 212°, while that at the melting point of ice is labeled 32°. The space between these points is divided into 180 equal parts, each one of which represents one degree.

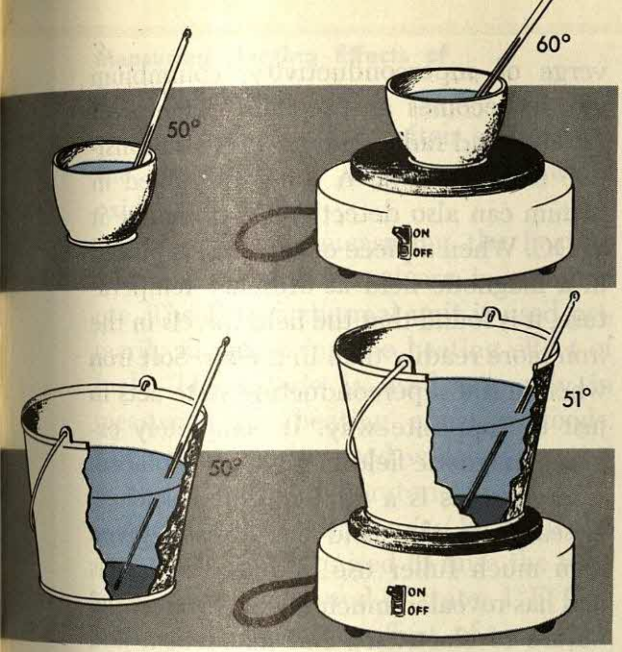
The centigrade thermometer shows the boiling point of water as 100° and the melting point of ice as 0°. The distance between these two points is divided into 100 equal parts. The centigrade thermometer is used for all purposes in all European countries except England, and in all scientific laboratories.

It is often necessary in the laboratory to change the temperature reading on a Fahrenheit thermometer to the corresponding centigrade reading. This is done very simply by subtracting 32° from the Fahrenheit reading and dividing the result by 1.8. For example, if your Fahrenheit thermometer reads 68°, the centigrade reading is 20°. To change from a centigrade reading to a Fahrenheit reading, multiply the centigrade reading by 1.8 and then add 32°. You can readily see that 10° centigrade is the same as 50° Fahrenheit. ($F = 10\ (1.8) + 32° = 18° + 32° = 50°$.)

Difference Between Temperature and Total Heat

On a hot summer day, you may find the temperature to be as high as 90° Fahrenheit. What does 90° Fahrenheit mean? Is the thermometer registering the total amount of heat energy in the air? No, it is not. Instead, it is registering merely the hotness or coldness of the air as compared with melting ice and boiling water. This is different from the total amount of heat energy in the air.

Suppose one thermometer were placed in a cup of water and another thermometer in a gallon pail of water, and it was found that the temperatures were the same. Now suppose both the cup and the pail were placed over gas flames of the same size. Which would be the first to show an increase of 10° in temperature? The water in the cup would. Which would require more heat energy to increase the temperature 10°? The water in the pail,



of course. Yet after the temperature of the water in each vessel has been raised 10°, the temperature of the water in the two vessels will again be equal. Evidently the thermometer does not measure total amount of heat energy the water gains from the gas flame.

To explain what a thermometer does measure, assume that when the temperatures were equal, the average velocity of molecules of water in the cup was the same as that of the molecules of water in the gallon pail. When the heat energy of the water in the cup and the water in the pail was increased, the average velocity of the molecules of water was increased. But since there were more molecules in the pail than in the cup, it took the gas flame longer to increase the average velocity of the molecules in the pail by a certain amount than to increase the average velocity of the molecules in the cup by the same amount. The thermometer reading, therefore, depends upon the average velocity of the molecules in a substance. Thus, when a thermometer registers 90° Fahrenheit, it is really indirectly comparing the average velocity of the molecules of air to that of the standard (the melting point of ice and the boiling point of water). (See page 254.) Its reading gives no indication of the total number of air molecules that are moving. The thermometer, therefore, does not measure the total amount of heat energy of the air.

Low-Temperature Science

If heat energy is only the motion of atoms or molecules, it is natural to wonder what would happen if molecular motion were stopped. In the first place, could molecular motion be stopped? If so, at what temperature? How would materials act under such a condition?

In 1848, the British scientist, Lord Kelvin, suggested that zero molecular motion was a logical consequence of the idea that heat energy is molecular motion. Why? Furthermore, he called this condition ***absolute zero temperature.*** He devised a temperature scale in which he used the centigrade degree, but made the zero represent absolute zero instead of the freezing point of water. This scale is known as the absolute or ***Kelvin scale*** (A or K), and it is still used by research scientists today.

For many years, it was thought that temperatures approaching 0°A, or 0°K could not actually be reached. Although scientists still have not reached absolute zero, they have reached 0.01°K and hope soon to reach 0.001°K. Research theory suggests that scientists may be able to reach only one-millionth of a degree away from absolute zero, and that absolute zero is probably as impossible to achieve as perpetual motion.

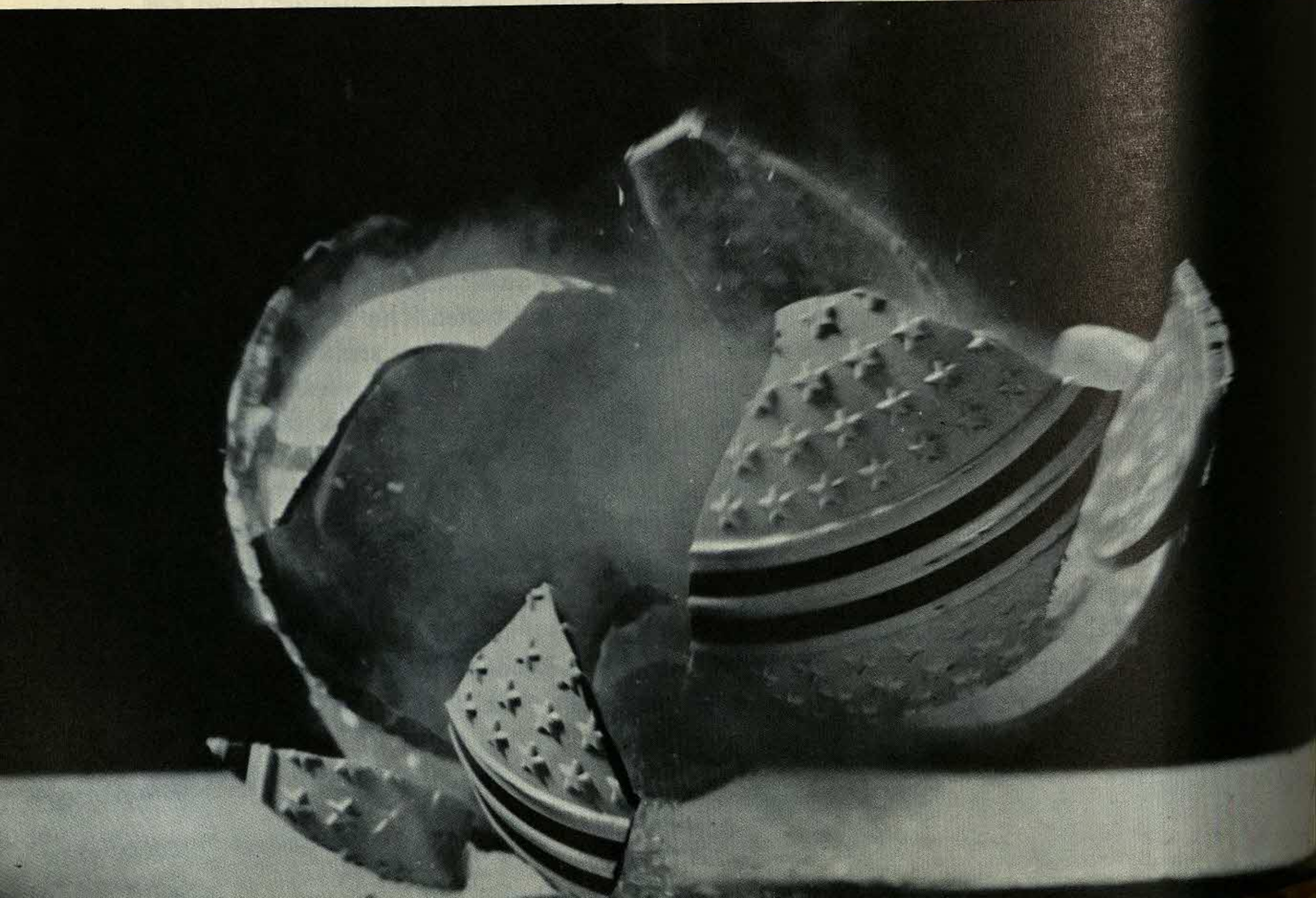
The branch of science dealing with very low temperatures is known as ***cryogenics.*** Research in cryogenics has revealed some unusual behavior on the part of matter. Certain electrical conductors lose practically all their resistance. For example, as mercury is cooled, its resistance drops steadily until, at about 4.3°K, it has about only 1/500 of its usual resistance. With further cooling, the resistance drops suddenly to less than one-millionth of its usual resistance. In this condition, it is called a ***superconductor.***

A great many materials suddenly become superconductors in the temperature range of 0.35°K to 15.0°K. When on the verge of superconductivity, columbium nitride becomes an excellent detector of infrared and radio energy. It is also sensitive to alpha rays. A tin wire chilled in helium can also detect AC and change it to DC. When a piece of soft iron is placed in a magnetic field at ordinary temperature, it is found that the field travels in the iron more readily than in the air. Soft iron when in the superconducting state acts in just the opposite way. It completely expels a magnetic field in which it is placed.

Cryogenics is a relatively new science. Research in this field has already given man much fuller use of many materials and has revealed much about the essential nature of electricity and magnetism and of the structure of matter.

A rubber ball, chilled to an extremely low temperature, shatters like glass when dropped on a table.

The International Nickel Co.



Measuring Heating Effects of Fuels and Foods

Fuels and foods are often selected on the basis of their heating effect when oxidized.

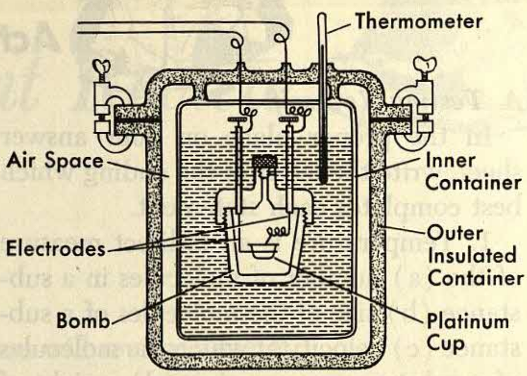
Two units for measuring the heating effect of fuels and food are in common use. The British thermal unit is used primarily in measuring the heating effect of fuels. The calorie is used primarily in measuring the heating effect of foods. The calorie is also used widely as a unit of heat in science laboratories.

The British thermal unit (BTU) is the amount of heat required to raise the temperature of one pound of water 1°F. The heat value, or heating effect, of most fuels is given in Btu's. Fuel used in home furnaces, for instance, has a heat value ranging between 18,000 and 20,000 Btu's per pound.

As you know, there are two kinds of calorie units, a ***large Calorie*** and a ***small calorie.*** A large Calorie is the amount of heat required to raise the temperature of one kilogram of water 1°C. A kilogram is a metric unit of measurement equal to about 2.2 pounds. The small calorie is the amount of heat energy that is required to raise the temperature of one gram of water 1°C. Since a gram is one-thousandth of a kilogram, the small calorie is one-thousandth of the large Calorie. The heat value of foods is expressed in calories.

The actual measuring of the heating effect, or ***caloric value,*** of a substance such as a fuel or a food is a difficult process. The apparatus used for this purpose is called a ***calorimeter.*** It consists of a large container constructed to prevent loss of heat energy from its interior. Inside this container is a smaller one, which holds one liter (1,000 grams) of water. A third, still smaller container is suspended in the water. Suppose one gram of the material to be tested is burned inside the smallest container. The heat energy produced as the material burns raises the temperature of the surrounding water. The increase in temperature is measured with a thermometer. The caloric value of the material burned is determined from the increase in the temperature of the liter of water. For example, if the temperature of the liter of water increased 1°, caloric value of material burned was one calorie per gram.

CALORIMETER



SUMMARY

The temperature of a substance is an indirect comparison of the average velocity of its molecules or atoms with that of a standard, water. Temperatures are measured with thermometers. The total amount of heat energy which a substance contains depends both upon the temperature of the substance and the total number of molecules it contains. Through oxidation, food and fuels produce a heating effect. This effect can be measured in definite units with a calorimeter.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Temperature is an indirect measure of the (a) number of molecules in a substance (b) size of the molecules of a substance (c) velocity at which the molecules of a substance are moving (d) weight of the molecules of a substance.

2. When mercury is heated it (a) expands (b) contracts (c) does not change its volume (d) becomes a solid.

3. If water at 100°C were measured with a Fahrenheit thermometer, it would have a Fahrenheit temperature of (a) 0° (b) 32° (c) 212° (d) 132°.

4. The heating value of food is most often measured in (a) Btu's (b) gram calories (c) kilogram calories (d) degrees.

5. A kilogram is equal to (a) 2.2 pounds (b) 500 grams (c) 1,000 pounds (d) 2,000 pounds.

6. The science that studies the characteristics of matter at extremely low temperatures is (a) cybernetics (b) cryogenics (c) thermodynamics (d) solid-state research.

7. The thermometer on which the zero mark does not correspond to any remarkable change of state in matter is (a) centigrade (b) Kelvin (c) Fahrenheit (d) none of these.

B. Recognizing Assumptions

Bill read in his science book that fuels give off different amounts of heat when they are burned. To gather some evidence to test this statement, he obtained three equal-sized beakers, put the same amount of water in each beaker, and placed them on a ringstand. He placed a thermometer in each beaker. Two inches below each beaker he placed a small container. He poured a sample of alcohol into the first container, gasoline into the second, and kerosene into the third. He lighted each fuel, and, after it had burned, he measured the temperature of the water in the beaker above it. He found that the temperatures of the water in the three beakers were not the same after the samples of fuel were burned. He concluded that his results proved the statement in his book.

On your answer sheet, write the number of each of the following statements which is an assumption that, if the tests were carried out exactly as described, you would have to accept before you could agree with Bill's conclusion.

1. Kerosene, alcohol, and gasoline are fuels.

2. Temperature of water in beakers was the same before the fuel was burned.

3. Equal amounts of each of the fuels were burned under each beaker.

4. Each fuel sample was two inches below the beaker.

5. The increase in temperature of the water in each beaker was caused only by the heat from the fuel under the beaker.

6. A thermometer can be used to measure temperature.

7. All of the heat produced by each fuel was used to increase water temperature.

8. Equal amounts of water were used.

9. Similar differences would be found if all fuels had been tested.

10. Three beakers were of the same material.

Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the more important ideas in the unit.

1. How is a model of electricity useful to a scientist?
2. What explanation is offered for the difference between conductors and insulators?
3. How is the potential difference produced with a generator related to the work required to operate the generator?
4. Is there always AC from the secondary of a transformer?
5. How can we obtain DC from an AC generator?
6. What is the significance of the statement that resistance is only a ratio of voltage and current?
7. Why cannot AC be used directly in electroplating?
8. How can an ammeter be modified to make it a voltmeter?
9. What is the difference between a coulomb and an ampere?
10. Why was it unfortunate that potential difference was also called electromotive force?
11. What similarity do the units ampere and watt have?
12. Why do we pay for kwh of electricity rather than for watts?
13. Why is language often a handicap in accurate thinking about heat energy?
14. What evidence is given to support the view that heat energy is present in all materials as found on the earth?
15. Why must some heat energy be used to raise the temperature of any material above that of its surroundings?
16. What is the basic difference between ordinary ways of securing usable heat energy and ways of securing it from nuclear fission?
17. What is the difference between the temperature and the total heat energy of a material?
18. How does a large Calorie differ from a small calorie?
19. What inaccurate idea may result from saying, "Heat energy comes to earth from the sun"?

B. Words in Science

Tell how the words, or terms, in each pair below are related to one another, or explain the difference between them.

alternating current
direct current

conductor
insulator

series
parallel

burning
exothermic

short circuit
open circuit

dry cell
storage cell

voltmeter
ammeter

temperature
total heat energy

watt meter
watt-hour meter

ampere
watt

temperature
molecular velocity

degree Fahrenheit
degree centigrade

C. Solving Mathematical Problems

Solve each of the following problems and write its answer on your answer sheet.

1. An electric lamp having a resistance of 40 ohms is connected across 80 volts. What will be the current rate in the lamp?

2. A hot plate is being designed for use across a potential difference of 115 volts. What must its resistance be to limit the current rate to 5 amperes?

3. An electric lamp has a resistance of 12 ohms, which limits the current rate to 0.5 amperes. What voltage should the source operating the lamp furnish?

4. The potential difference across the secondary coil of an ideal transformer would be 6,600 volts when its primary coil is connected to 110 volts. What is its turns ratio?

5. An ideal transformer has 100 turns on the primary and 10 turns on the secondary. What would be the voltage across the secondary coil when there were 1,000 volts across the primary coil of the transformer?

6. A television set is marked 300 watts and was used four hours each day for thirty days. If electricity costs 3¢ per kwh., how much did it cost to operate the set?

7. How many grams of silver (Ag) would be deposited in an hour when the current rate is one ampere?

8. The atomic weight of zinc is 65.38, and each ion has a +2 charge. What weight of zinc would a coulomb of charge deposit on the negative electrode?

You Can Go Further

A. BY COLLECTING ADDITIONAL EVIDENCE

1. Take a trip to an electric power plant to observe operations.

2. Examine a house in the process of construction and note the precautions taken to make the electrical wiring safe.

3. Visit an electric-motor repair shop to see how motors are tested and rewired.

B. BY PREPARING REPORTS ON SPECIAL TOPICS

1. The theory and operation of the solar battery
2. A model to help explain transistor operation
3. The heating equivalent of an electric current
4. The relationship of peak, RMS, and average voltage of AC and DC voltage.
5. Ohm's Law for circuits with reactance
6. Electrical conduction at very low temperatures
7. On low-temperature research in cryogenic laboratories
8. On calorimeters and their use.
9. On high-temperature furnaces
10. On thermometry through the ages
11. On overcoming the thermal barrier

C. BY READING

ATKIN, J. MYRON. *Electricity and Magnetism.* New York: Rinehart and Company, Inc., 1958.
Includes simple demonstrations and experiments.

BUEHR, WALTER. *Wonder Worker, the Story of Electricity.* New York: William Morrow and Company, Inc., 1961.
Provides a clear, simple explanation of how electricity works.

EFRON, ALEXANDER. *Heat.* New York: John F. Rider Co., Inc., 1957.
Covers basics of heat.

RUCHLIS, HY. *The Wonder of Heat.* New York: Harper & Bros., 1961.
Explains all aspects of heat energy with the aid of diagrams.

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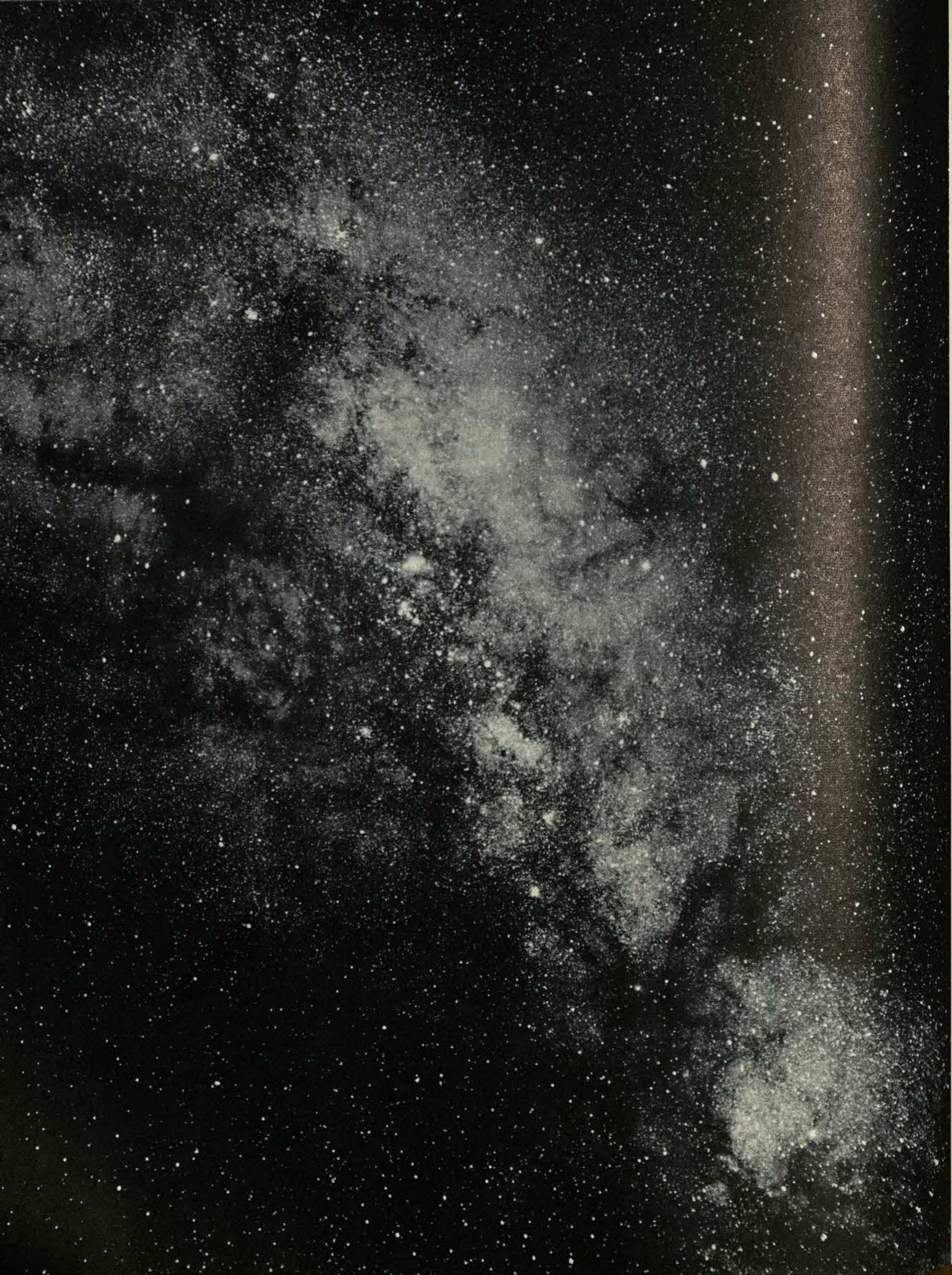
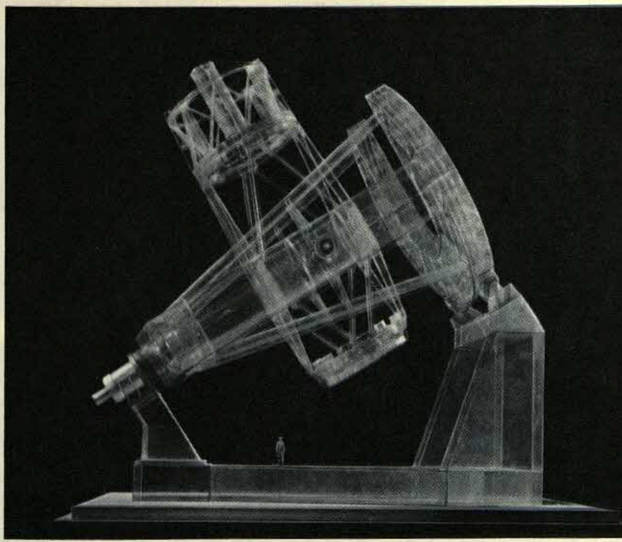
Library
Calcutta
25/3, B. C. Ro



Mount Wilson & Palomar Observatories


American Museum of Natural History

UNIT 6

The Universe

STATE INSTITUTE OF EDUCATION
Govt. of West Bengal

"What a beautiful sight!" radioed astronaut Alan B. Shepard from his capsule as he became the first American to see the earth from outer space.

"What a ride!" exclaimed Shepard as he climbed out of the capsule.

"What a man!" thought those on earth who hopefully waited for his safe return from that memorable journey on Friday, May 5, 1961.

Curious men throughout the ages have been venturing into the unknown for answers to their questions about the earth and the heavenly bodies that seem to surround it. They have wanted to know, "What's on the moon? Is there life on other planets? What are comets? What are stars? From where did they come? How many are there? How big is it all? Are there other earths like our own?"

Some questions have been answered, but there are still others unanswered. For each question that is answered, many new ones are raised. So complex are some of them that years of the life of one scientist may be spent in searching out bits of information which, when put together, supply only a part of an answer to one question. And so the fascinating search continues.

PROBLEM 1: HOW HAVE SCIENTISTS STUDIED THE UNIVERSE?

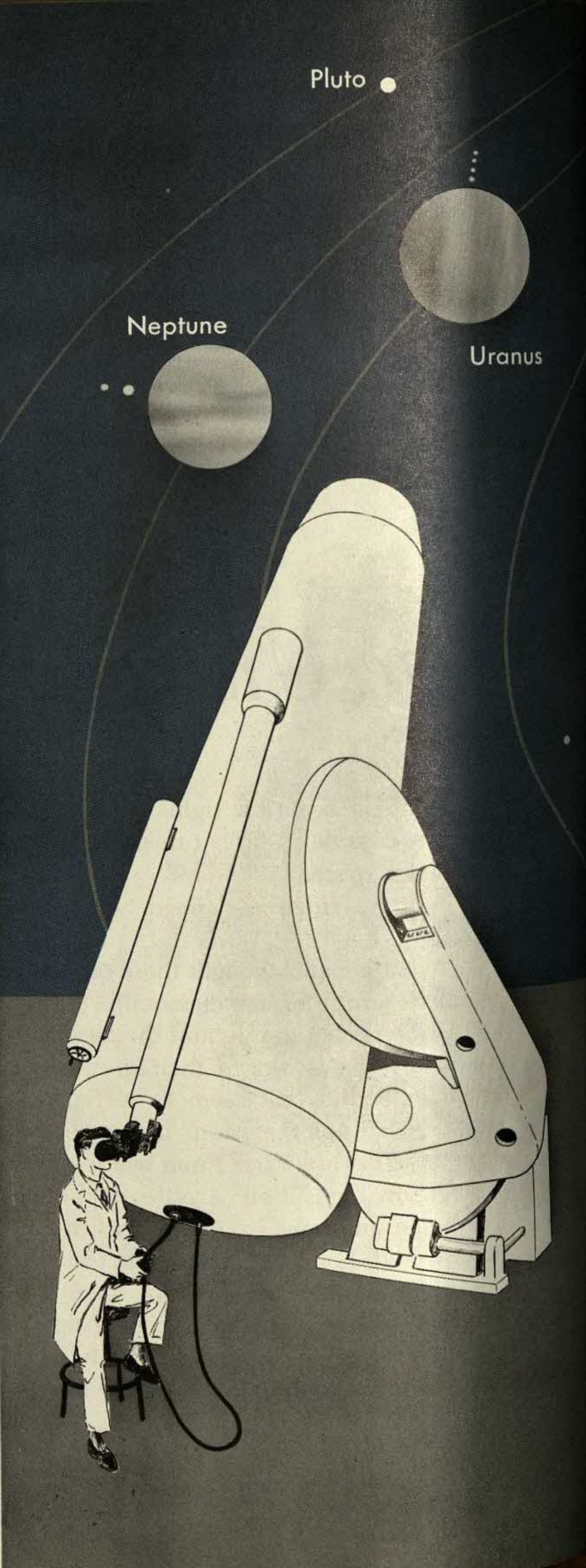
From ancient times, man has wondered about the stars and other bright objects in the sky. These he has referred to as ***celestial bodies.*** From man's attempts to describe and explain celestial bodies, ***astronomy,*** one of the oldest of the sciences, was born. The word astronomy comes from Greek words—"*astro,*" meaning star, and "*nōmos,*" meaning law or custom. Through long and careful study of celestial bodies, man has been able to explain many things about them. Some of these explanations have become basic principles. In this problem you will learn how some of these principles were developed.

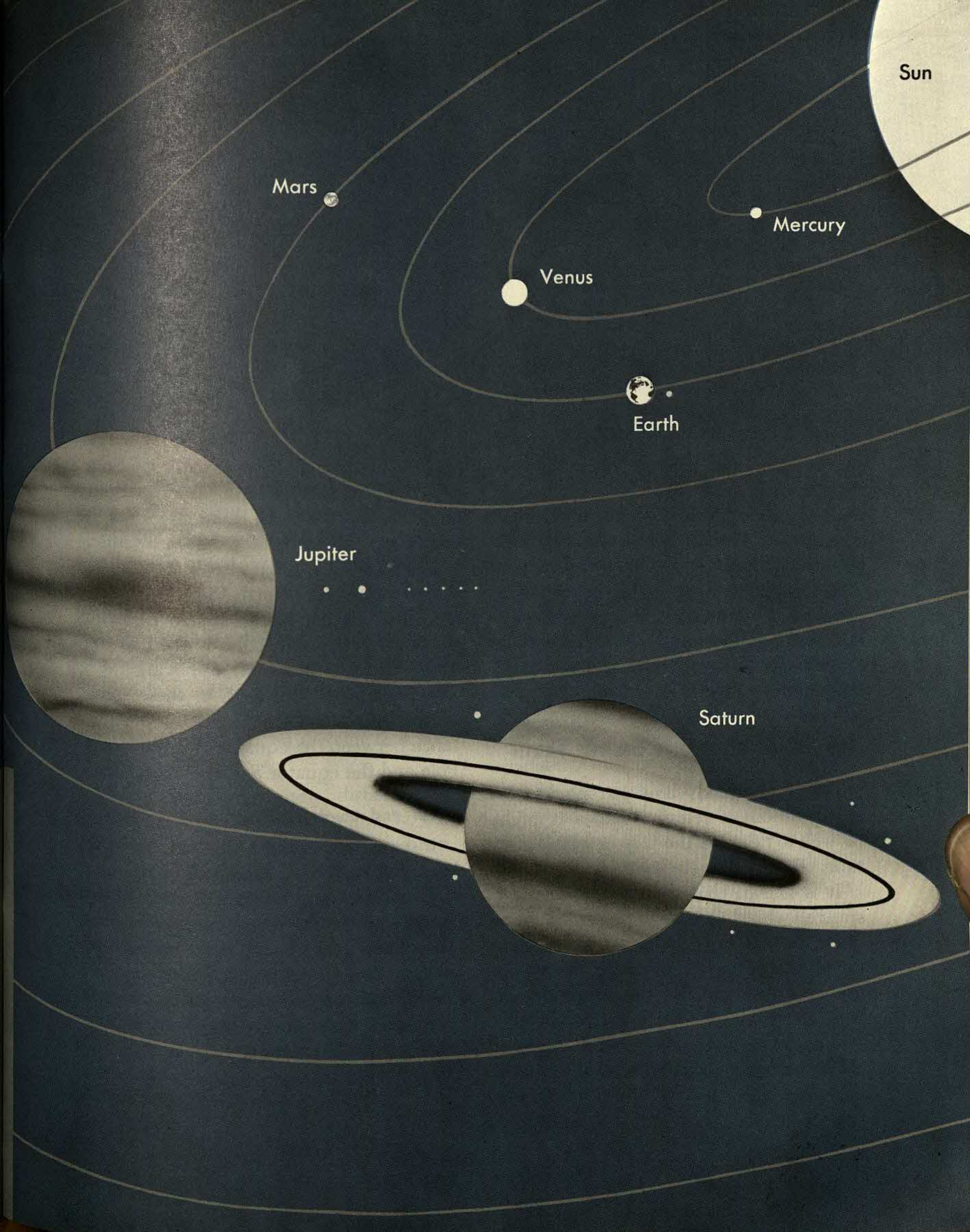
THE NATURE OF ASTRONOMY

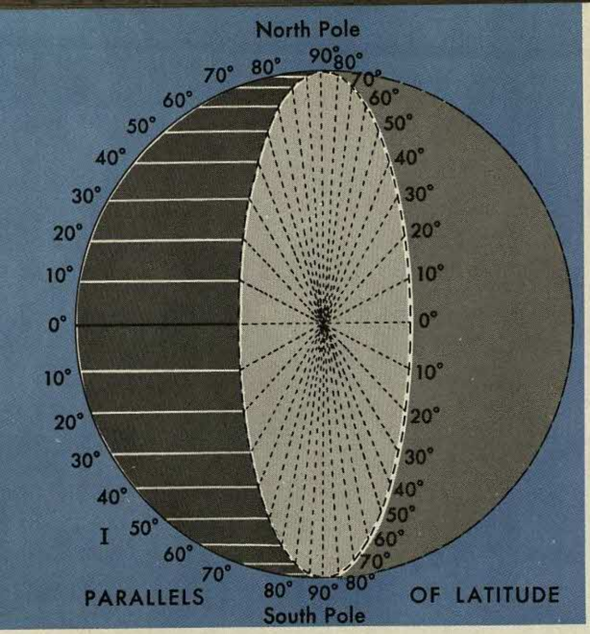
One part of astronomy deals with a description of the positions, movements, sizes, and brightness of celestial bodies. The other part deals with attempted explanations of why celestial bodies move, how they get their energy, how they are formed, and why they change.

Man has long observed that the sun, moon, planets, and stars move across the sky each day. It is now known that this movement can be accounted for by the rotation of the earth on its axis once every twenty-four hours.

Before this fact was known, the ancients thought that the celestial bodies were revolving around the earth. Astronomers explained the apparent motion of celestial bodies by imagining the sky to be a large




Sun
Mars
Mercury
Venus
Earth
Jupiter
Saturn



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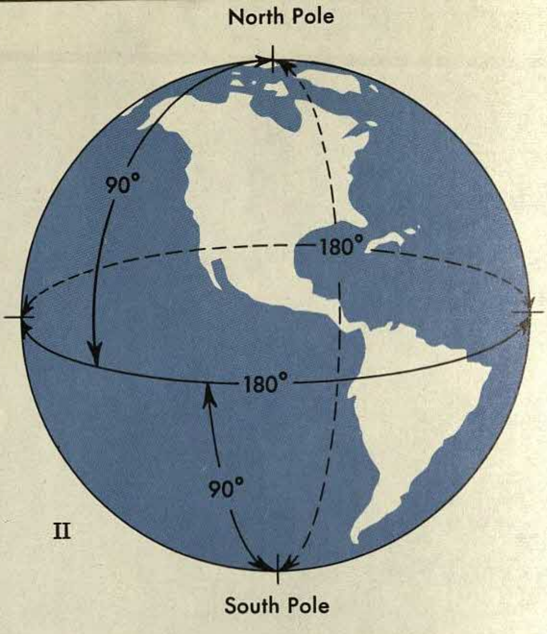


II

curved dome, or sphere. They thought that the sun and other celestial bodies were attached to this sphere, which was constantly turning. This turning supposedly accounted for their movement across the sky. Even today astronomers use their imaginations to help them locate the positions of stars and describe their movements. Scientists must have good imaginations to find out things.

LOCATING POSITIONS ON THE EARTH

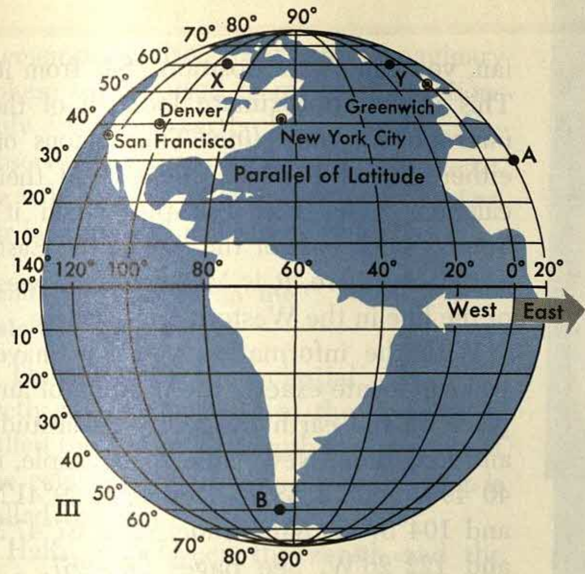
Before you study how astronomers locate positions of celestial bodies, it might be well to describe the way in which positions on the earth are located.

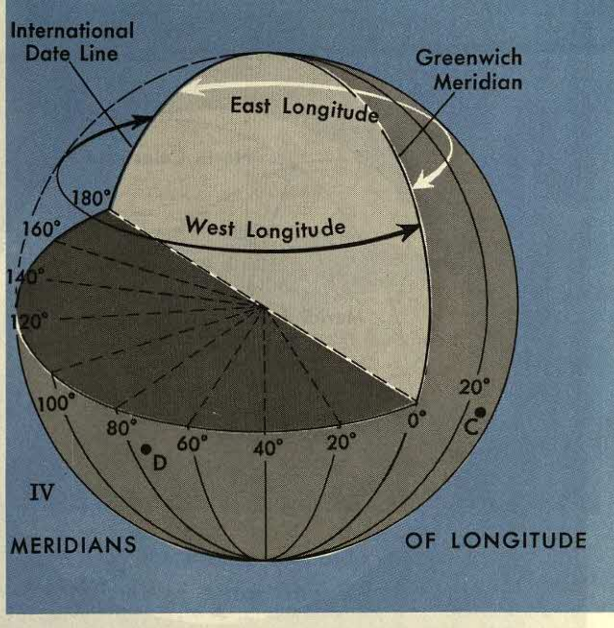
It is known that the earth is nearly a sphere, which can be represented by a globe. If you will look at your classroom globe, you will see that circles have been drawn around it. They represent imaginary circles on the surface of the earth. The ***equator,*** for example, is an imaginary circle halfway between the North Pole and the South Pole. The equator is also a ***great circle.*** A great circle is the largest circle around the earth. Like all circles, it can be divided into 360 parts, or ***degrees.***

Any number of great circles can also be drawn through the North and South Poles. On these circles, the distance between the North and South Poles is one half the entire circle, or a ***semicircle*** having 180°. The equator divides each of these semicircles into equal parts of 90°—the distance between the equator and the North Pole and the equator and the South Pole.

North and South Positions on the Earth

If you draw around a globe of the earth lines that are 1°, 2°, 3° and so on north of the equator, you will finally reach the North Pole at 90°. You can draw similar lines down to the South Pole. Because all of these lines go around the earth parallel to the equator, they are called ***parallels of latitude.*** Latitude is distance in degrees north or south of the equator. For any place that lies on any one of these paral-





lels, you can now tell the distance in degrees north or south of the equator.

To find the exact distance north or south of the equator of a point lying, say, between 45° and 46°, you need a smaller unit than a degree. Each degree, therefore, has been divided into 60 parts called ***minutes*** (′), and each minute has been divided into 60 parts called ***seconds*** (″). These subdivisions of degrees are not the same as the minutes and seconds that you use when telling time.

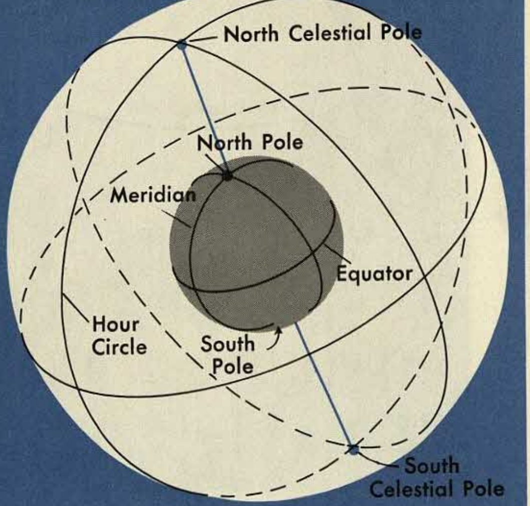
With these smaller units, distances on the earth can be measured accurately. On this page, you will see that lines have been drawn on globe III at 30° intervals north and south of the equator. Line A is 30° north latitude, that is, it is 30° north of the equator. Line B is 60° south latitude. If a certain position were 65 degrees, 30 minutes, and 5 seconds south of the equator, its position would be written as 65°30′5″S. By using this system, you can now locate the north, or south, position of any place on the earth.

East and West Positions on the Earth

Although points X and Y, shown on globe III, are both 60° north latitude, they are not in the same place. Y is east of X. Before you can locate a place exactly, you must be able to tell its position east or west as well as north or south.

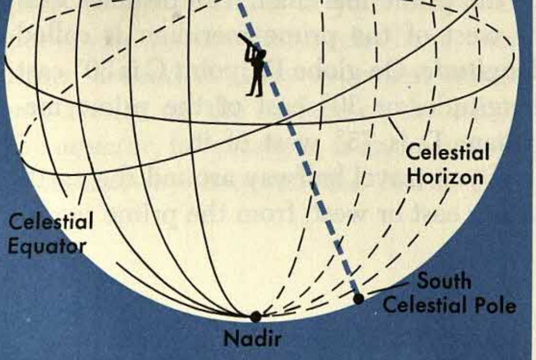
You have just learned that many imaginary great circles can be drawn around the earth through the North and South Poles. Each line from pole to pole is called a ***meridian.*** At an international conference in 1884, the meridian passing through Greenwich, England, was accepted as the ***prime meridian,*** and its position was designated as 0°. Every point on the earth lies on some meridian. Its position is given as the number of degrees it lies east or west of the prime meridian. The distance east or west of the prime meridian is called ***longitude.*** On globe IV, point C is 30° east longitude, or 30° east of the prime meridian; D is 75° west of it.

If you travel halfway around the earth, either east or west, from the prime merid-



In fixing locations of stars and planets, astronomers use a celestial sphere, shown above. You can get some idea of what this is like by imagining that the earth's lines of latitude and longitude have been projected into outer space.

The celestial equator, in the diagram below, is halfway between the celestial poles. It is in the same plane as the earth's equator. Zenith is directly overhead; nadir is directly underfoot.



ian, you come to a position 180° from it. This is the approximate location of the ***international date line.*** The regions on either side of it differ one day in their calendar date. For example, when it's Sunday noon east of the line in the Eastern Hemisphere, it is Monday noon west of the line in the Western Hemisphere.

With the information you now have, you can locate exactly the position of any place on the earth by giving its latitude and longitude. New York, for example, is 40°49′N and 73°58′W. Denver is 39°41′N and 104°57′W. San Francisco is 37°47′N and 122°26′W. See pages 266–267.

THE CELESTIAL SPHERE

As you have just learned, man is able to locate exact positions on the earth by using imaginary circles running north-south and east-west around the earth. Astronomers have developed a similar imaginary system for locating celestial bodies in the sky. The system is called the ***celestial sphere.***

The celestial sphere is not the same as the one to which the ancients thought all celestial bodies were attached. It is an apparent sphere which extends an unlimited distance out into space. In this sphere, an observer on the earth is located in the center of it, as shown in the diagram. Although all the stars seen in the dome-shaped night sky may appear to be the same distance from the earth, it is now known that they are not.

Remember that this celestial sphere is to be used only to locate the positions, or directions, of celestial bodies without reference to their distances from the earth.

Remember, also, that this imaginary sphere can be used to make observations only from the earth. When man makes observations from other positions in space, he will have to invent a different system for locating things he sees. Why?

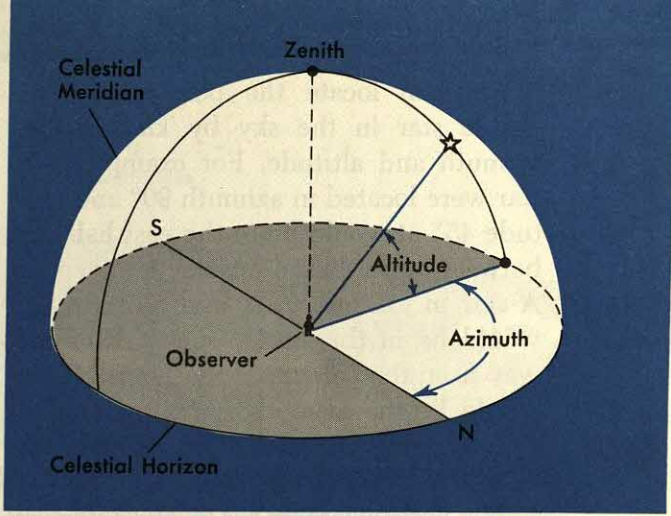
Points and Circles on the Celestial Sphere

The point of the celestial sphere directly above the head of the observer is called the *zenith* (ZEE-nith). The point of the celestial sphere directly underfoot is called the *nadir* (NAY-deer).

Halfway between the zenith and the nadir on the celestial sphere is the great circle which astronomers call the ***celestial horizon.*** This circle is 90° from both the zenith and the nadir. It is not in the same position as the irregular, visible horizon where the earth and sky seem to meet, since the visible horizon is less than halfway between zenith and nadir. The celestial horizon is an imaginary circle on the celestial sphere which is used in describing the position of stars.

Other circles, called ***vertical circles,*** are also imagined as being located on the celestial sphere. They pass through zenith and nadir, and are, therefore, perpendicular to the celestial horizon. North and south points on the celestial horizon are located in the direction of the sky's North and South Poles. The celestial poles are directly over the earth's North and South Poles.

The vertical circle above the observer, which passes through the celestial poles and crosses the horizon at its north and south points, is called the ***celestial meridian.*** At right angles, or 90° from the celestial meridian, the vertical circle that crosses the horizon at its east and west points is called the ***prime vertical.***



With the aid of the diagram above, you can locate the azimuth of a star. The angle shown in the white area is the azimuth. It is measured eastward along the horizon from north point.

If you imagine a vertical circle through the position of a star, the circle will, of course, cut the celestial horizon. Then you can measure the distance in degrees between the north point of the celestial horizon and the point where this vertical circle cuts the horizon. This distance is called the ***azimuth*** of that star. The azimuth of a star is measured completely around the horizon from 0° to 360°, depending on the location of the star on the celestial sphere. It is measured in degrees.

By the horizon system, one other distance is needed to locate the position of a star. This is the ***angular distance,*** or ***altitude,*** of a star above the horizon. The angular distance is the number of degrees in the angle formed by imaginary lines from the observer to the star and from the observer to the horizon.

You can locate the position of any visible star in the sky by knowing its azimuth and altitude. For example, if a star were located in azimuth 90° and altitude 45°, it would be in the east halfway between the celestial horizon and zenith. A star in azimuth 180° and altitude 30° would be in the south, one-third of the way from the horizon to the zenith. What would be the azimuth and altitude of a star in the west, two-thirds of the way from the horizon to zenith?

The horizon system for locating stars on the celestial sphere is not very complicated. It is much like the system of latitude and longitude which is used for locating positions on the earth. The horizon system can be used to describe the position of stars at any particular time from a particular place on the earth. But the azimuths and altitudes of stars are always changing because of the apparent daily rotation of the celestial sphere. This makes it necessary, for certain purposes, to use other more complicated systems. They, too, are based upon imagined points and circles on the celestial sphere. If you ever go on to study astronomy, you will learn about the other systems. In one of these systems the north and south celestial poles and a celestial equator are used as the reference points for locating celestial bodies.

The celestial sphere and all points and circles on it are apparent systems astronomers invented to describe position and movement of stars in angular distances.

STARS

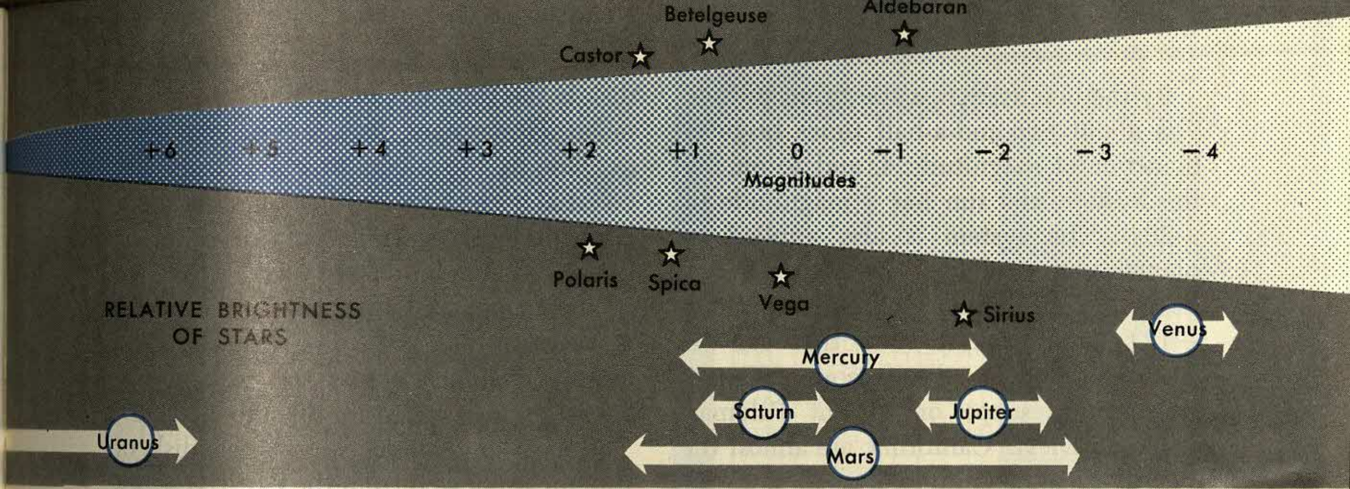
In your earlier study of science, you probably learned something about the constellations shown on the star maps at right. These are groups of stars named by people in ancient times for gods and animals in their mythology. Today, there are eighty-eight recognized constellations. These names have no scientific basis. However, astronomers still use the constellations to mark off regions on the celestial sphere. These regions are useful in describing the approximate positions of stars and planets.

Brightness of Stars

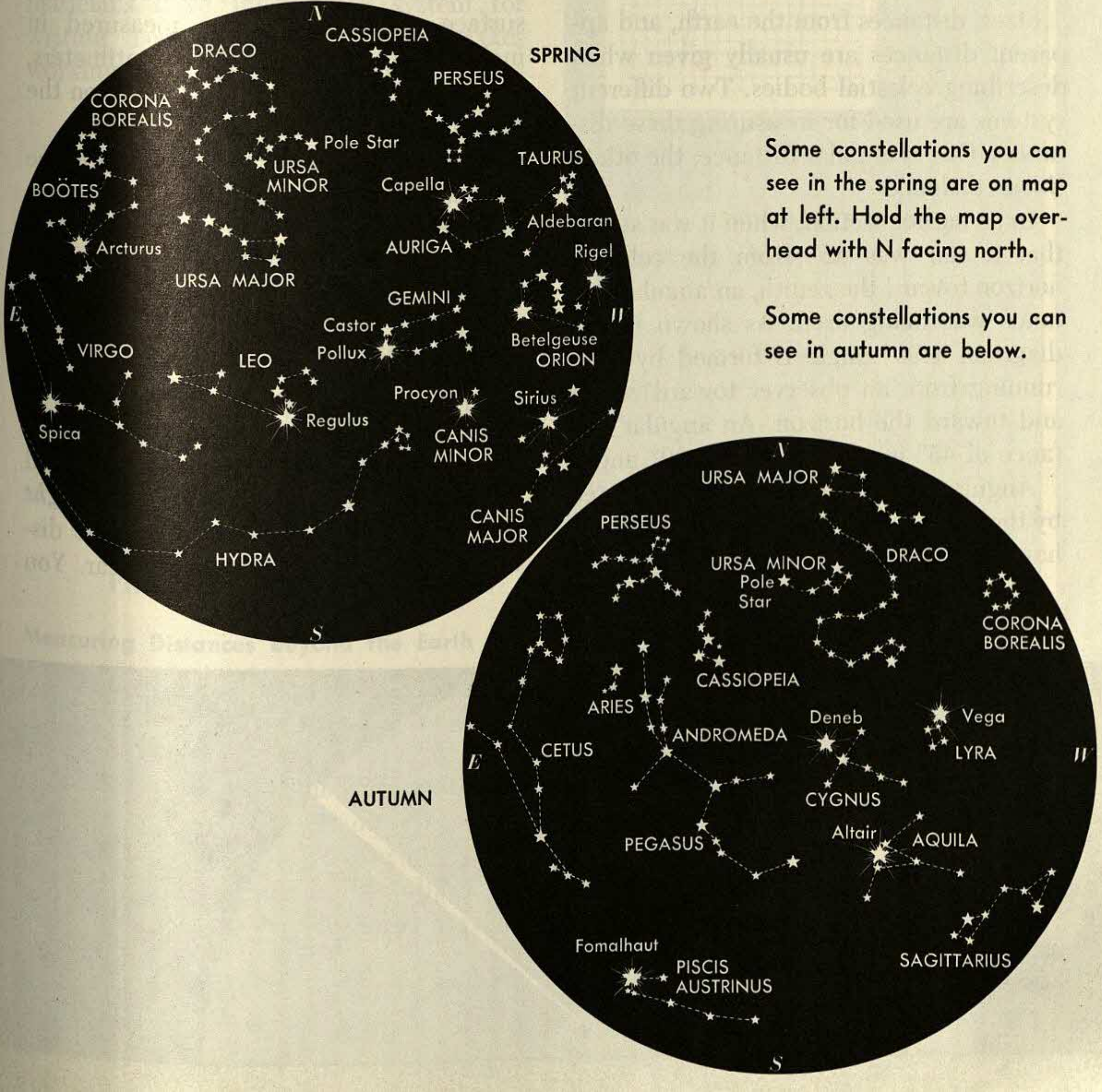
Early astronomers developed a system of classifying stars, based upon their apparent brightness. The twenty brightest were put into one class and called first magnitude stars. Stars that were less bright were put into the second-magnitude class, and so on. For example, Polaris and stars in the Big Dipper are second-magnitude stars. All visible stars were grouped into one of six classes. The first-magnitude stars are the brightest and the sixth-magnitude stars are the faintest, according to naked-eye observation.

Since the invention of the telescope, many more stars were discovered. In order to classify them according to brightness, many more magnitudes were required. A new scale had to be invented.

On the new scale, zero-(0) magnitude stars are brighter than first-magnitude stars. Stars classified as minus one-(−1) magnitude stars are brighter than zero magnitude. On the other end of the scale, the dimmer stars are classified from seventh-magnitude on up. For example, the magnitude of the brightest star outside of the solar system, Sirius, is −1.6, whereas the magnitude of Aldebaran, a red star, is 1.1.



The chart above shows the relative brightness of some of the major stars and the visible planets.



Some constellations you can see in the spring are on map at left. Hold the map overhead with N facing north.

Some constellations you can see in autumn are below.

By the new system, a star of magnitude 3 is about two-and-a-half times brighter than one of magnitude 4, and so on. By this system, the sun has a magnitude of −26.8. The system is also applied to planets and satellites. The planet Venus has a magnitude of −4.4 and the moon −12.6. The faintest stars that can be photographed by the famous 200-inch reflector telescope on Mount Palomar, near San Diego, California, are almost the twenty-third magnitude.

Distances From the Earth

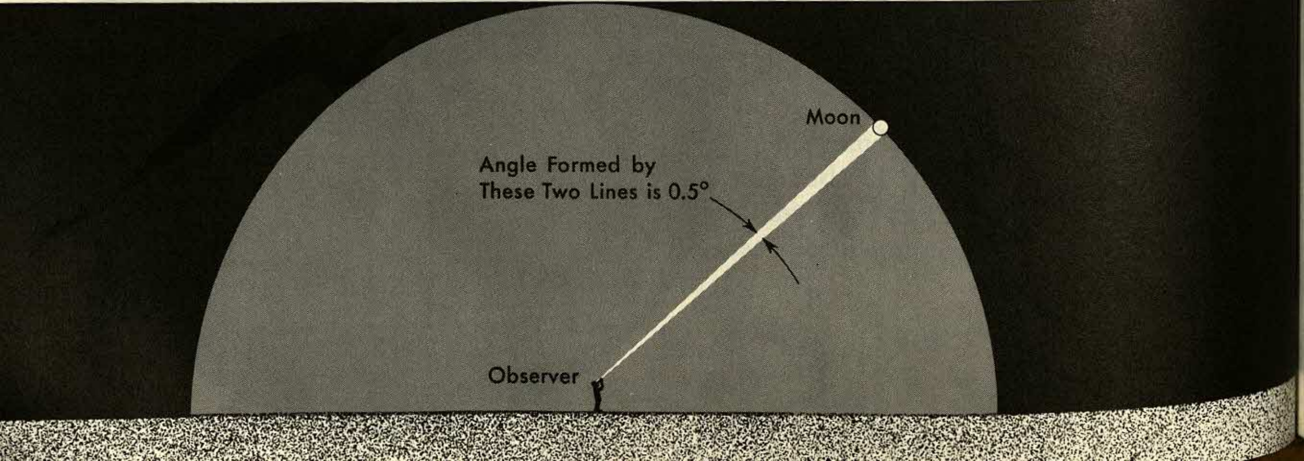
Sizes, distances from the earth, and apparent distances are usually given when describing celestial bodies. Two different systems are used for measuring these distances. One is angular distance; the other, ***linear distance.***

In an earlier section, when it was stated that a star was 45° from the celestial horizon toward the zenith, an angular distance was being used. As shown in the diagram, a 90° angle is formed by lines running from an observer toward zenith and toward the horizon. An angular distance of 45° is one half of the 90° angle.

Angular distance can also be illustrated by the moon, earth, and sun. You no doubt have observed the ***disk*** of a full moon. A disk is the thin, flat circular shape of the moon. How many disks would you need as wide as the moon to reach from the celestial horizon to zenith if the disks were laid side by side? You would need 180 of them. The angular distance across the disk of the moon, as viewed from the earth, is, therefore, 90/180°, or ½° (0.5°). The angular distance across the disk of the earth, as viewed from the moon, is 2°. The angular distance across the disk of the sun, as viewed from the earth, is about the same as that of the moon, 0.5°.

Linear, or straight-line, distances on the surface of the earth are measured in inches, feet, and miles, or in centimeters, meters, and kilometers, depending on the system of measurement you choose.

It was not practical to measure the great distances beyond the solar system in miles or kilometers. Scientists, therefore, invented a system which could measure these great distances. Because the system had to be based on some known units of measurement, such as miles or seconds, they chose the speed of light, which is approximately 186,000 miles a second. However, a light second was not a large enough unit, so a ***light year*** was chosen. A light year is the distance that light travels in one year. You



can see that, in terms of miles, the light year is equivalent to a great distance.

You can compute the distance of a light year as follows:

a. 186,000 × 60 = distance of a light minute
b. light minute × 60 = light hour
c. light hour × 24 = light day
d. light day × 365 = light year

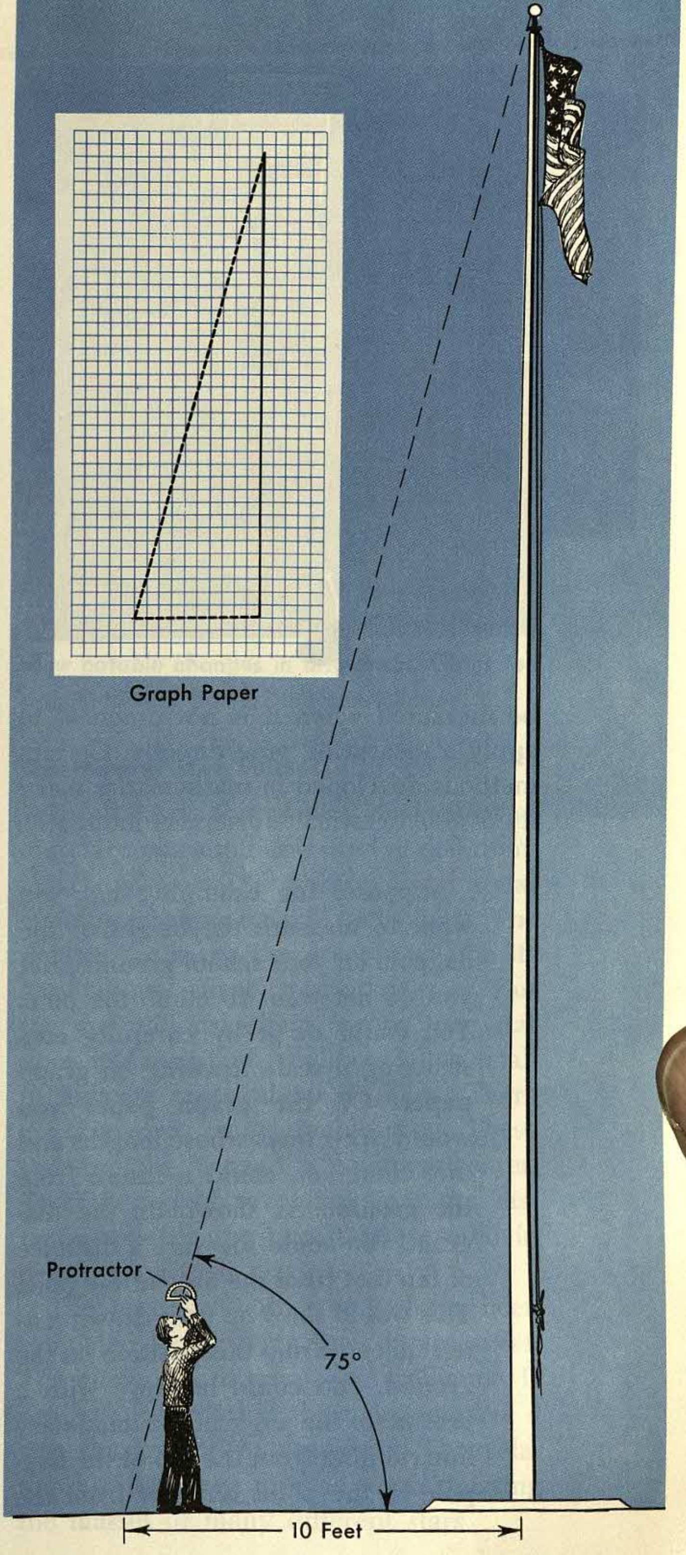
When you have done this multiplication, you will find that one light year equals 5,865,696,000,000 miles. This is a large number to write. As you will recall, mathematicians have invented a system for writing large numbers, which makes working with them much simpler.

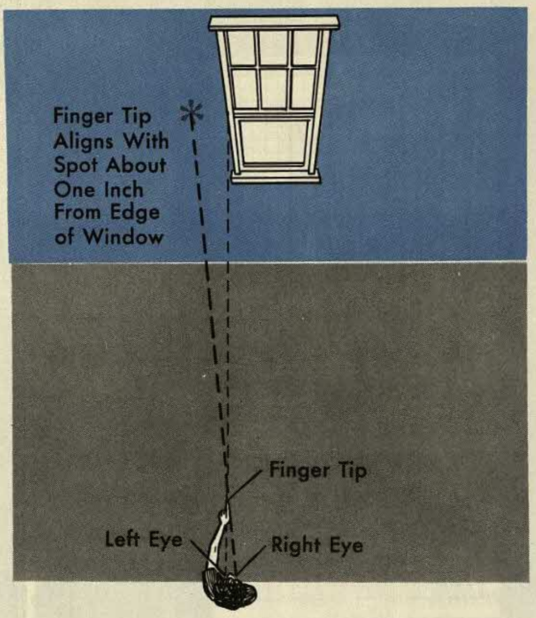
Here is something you can do to review the system. Below are the distances of the planets from the sun. Write them in the powers-of-ten system.

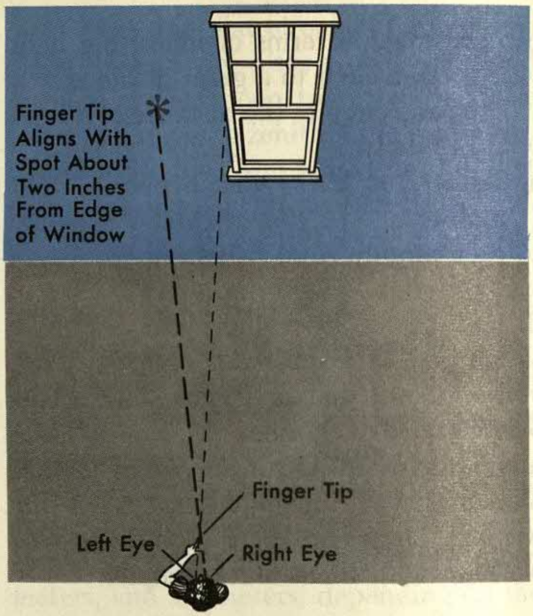
Mercury	**36,000,000 miles**
Venus	**67,000,000 miles**
Earth	**93,000,000 miles**
Mars	**142,000,000 miles**
Jupiter	**483,000,000 miles**
Saturn	**886,000,000 miles**
Uranus	**1,780,000,000 miles**
Neptume	**2,800,000,000 miles**
Pluto	**3,700,000,000 miles**

Measuring Distances Beyond the Earth

You can measure distances such as the length of your classroom, or the length of a football field, by using a tape measure marked off in feet. You do this by extending your tape measure from one end of the room or football field to the other. In other words, you measure the object directly. Often, however, distances have to




Finger Tip Aligns With Spot About One Inch From Edge of Window
Finger Tip
Left Eye
Right Eye


Finger Tip Aligns With Spot About Two Inches From Edge of Window
Finger Tip
Left Eye
Right Eye

be measured when it is not practical to apply a measuring tape directly. Certain methods developed in mathematics make it possible to estimate distances indirectly.

Suppose, for example, that you want to measure the height of the flagpole on your school grounds, but you do not want to climb the pole. You could do it by carefully constructing a scale drawing on graph paper. On the graph paper you would draw lines whose lengths and directions you could measure from the ground. As shown on the diagram, you could measure a distance of ten feet from the base of the pole. This would show on your drawing as ten spaces. From this position on the ground, you could measure with a *protractor* the angle of the imaginary line running from the top of the flagpole to the point ten feet from the base. A protractor is a device for laying out, or measuring, angles. The diagram shows you how to measure the angle. For purposes of illustration, assume the angle to be 75°. If you carefully draw the line on the graph paper to meet the vertical line representing the flagpole, you will find that it reaches that line at about 37 squares, or feet, above the base. The height of the flagpole has now been determined to be 37 feet.

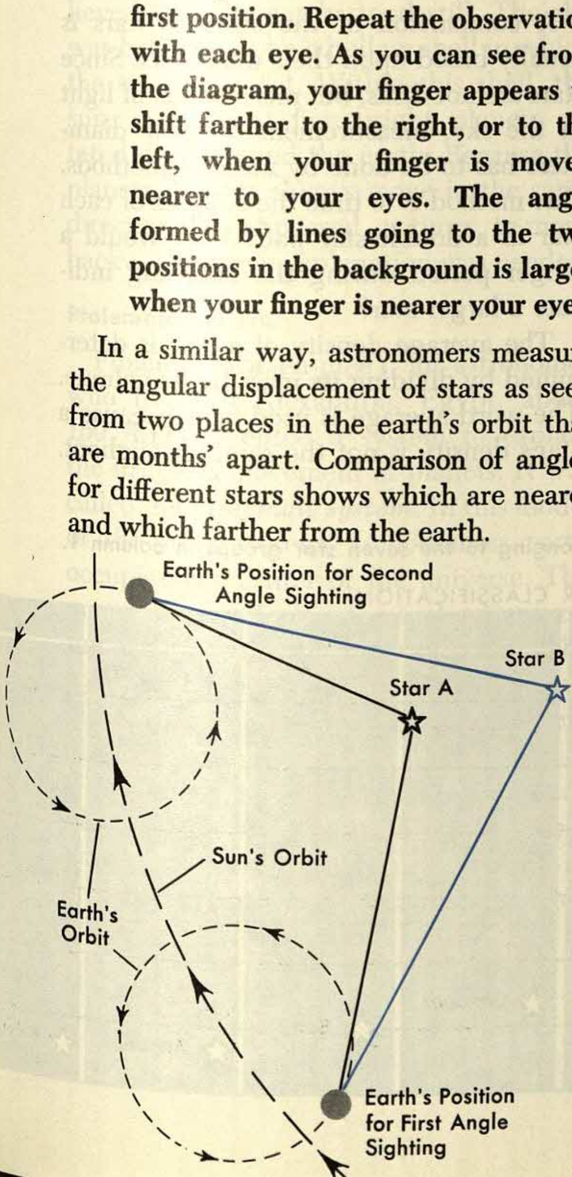
By using the mathematics of ***trigonometry***, the height of the flagpole could be found without making a scale drawing. Trigonometry deals with the relations between angles of right triangles and their sides. Astronomers have used trigonometry to find the distance to the moon and distances to certain stars.

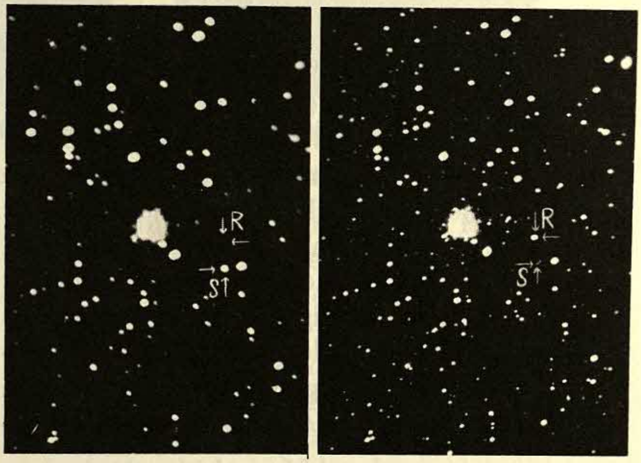
Here is something you can do to help you see that there is a relation

between distance and the angles formed by lines of observation. Hold your finger at arm's length, as shown in the drawing. Close your right eye and line up your index finger with the edge of some object across the room. Next, open your right eye and close your left eye while still looking at, and past, your index finger. Note that the position of your finger appears to have shifted.

Now bring your finger in about halfway between your eye and the first position. Repeat the observation with each eye. As you can see from the diagram, your finger appears to shift farther to the right, or to the left, when your finger is moved nearer to your eyes. The angle formed by lines going to the two positions in the background is larger when your finger is nearer your eyes.

In a similar way, astronomers measure the angular displacement of stars as seen from two places in the earth's orbit that are months' apart. Comparison of angles for different stars shows which are nearer and which farther from the earth.


Earth's Position for Second Angle Sighting
Star B
Star A
Sun's Orbit
Earth's Orbit
Earth's Position for First Angle Sighting



In this double photograph of the constellation Scorpius, above, the variable stars R and S show notable changes in brightness. Giant red star Antares is part of this constellation.

Determining Star Masses

In all cases, the gravitational effect of one star upon another is used in determining the masses. The more material a star contains, the greater will be its mass. The greater the mass, the greater will be its gravitational effect upon other stars. But the gravitational effect of one lone star upon its far-distant neighbors is too small to indicate much about its mass. There are, however, many double stars. These stars revolve around a common center. Their period of revolution and the distance between the two stars are used in determining their masses.

The masses of other stars have been estimated by studying their ***luminosities.*** The luminosity of a star is its brilliance. It has been found that the more massive a star, the greater its luminosity. This relationship has been used in approximating the masses of many different stars.

Determining Star Temperatures

Although the temperatures of stars are obtained by a rather indirect method, astronomers believe that they can determine the temperatures quite accurately.

The light which comes to the earth from the sun and other stars, as you learned in Unit 4, is made up of many different wave lengths. Light is broken up into its different wave lengths, called the ***spectrum***, when it is passed through a prism in a ***spectroscope***. A spectroscope is an optical instrument used in spectrum analysis.

STAR CLASSIFICATION

Star class	Approx. Temp. (degrees F.)	Color
O	over 55,000	Blue-white
B	36,000	Blue-white
A	20,000	White
F	13,500	Yellowish-white
G	11,000	Yellow
K	7,500	Orange
M	5,500	Red

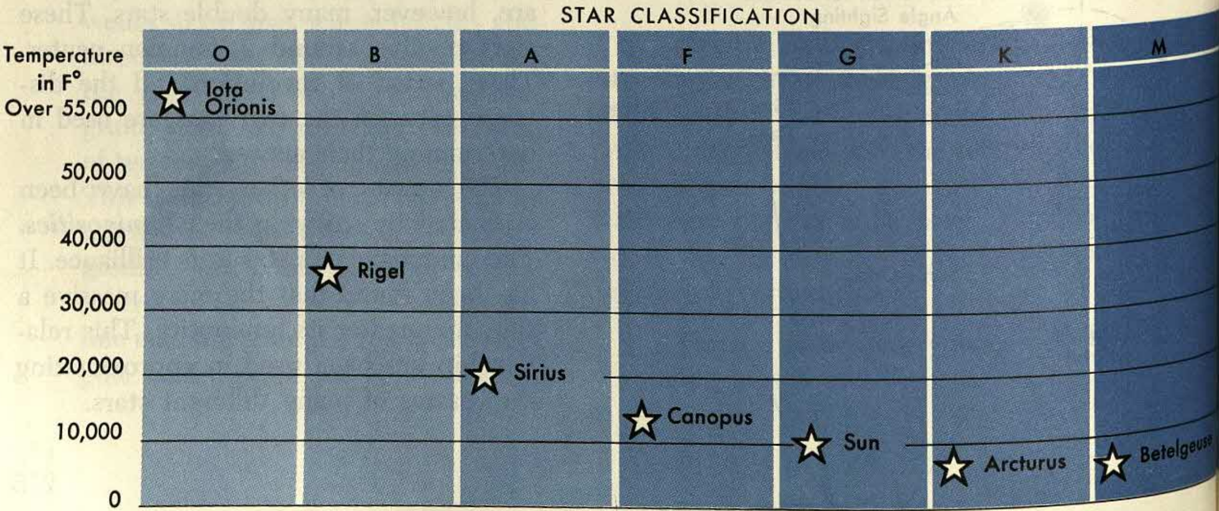
Although all stars have similar spectra, running from red to violet, some stars have more intense radiation in some parts of their spectra than others. Astronomers determine the temperature of such stars by measuring and comparing the intensity of their light at different wave lengths in their spectra. Astronomers generally measure temperatures on what is known as the Kelvin scale. See Unit 5, page 255.

Determining Diameters and Densities

A comparison of the sizes of stars is usually based upon their diameters. Since stars are not disks, but mere points of light in the sky, measurement of their diameters has to be done by indirect methods. One method is to time the eclipses of each star in a double-star pair. Why would a longer period during the eclipsing indicate a larger star?

The average density of a star is determined by dividing its mass by its volume. The word average is used here because a star's density is not the same throughout.

The chart below indicates temperatures of stars belonging to the seven star groups in column 1.



Yerkes Observatory

Eclipses of double stars by each other, such as Krueger 60, above, help determine their diameters.

The density in the center of a star may be twenty times greater than the average density of the star.

MOVEMENTS OF PLANETS

Less than 500 years ago, it was still believed that the earth stood still. The sky was believed to be a hollow shell in which the stars were set. Within this shell, the sun, moon, and five bright planets rotated daily around the earth. Because the planets did not always move in the same direction, but appeared, at times, to move backwards, some explanation was needed.

Ptolemaic System

Ptolemy (TOL-eh-mee), an astronomer who lived in Alexandria, Egypt, about 150 A.D., invented a system to explain the irregular movement of planets. It was called the ***Ptolemaic system.*** In this model of the solar system, a motionless earth occupied the center of the universe. The moon, sun, and planets revolved around the earth at different rates of speed. The stars were thought to be brilliant points of light set in a hollow sphere, which enclosed the earth.

According to Ptolemy's system, each planet not only revolved, in its orbit, around the earth, but it also revolved in a smaller circle whose center was located on the orbit.

If you study the diagram of the Ptolemaic system, you can see how this system might explain why the planets, when viewed from the earth, appear, at times, to be moving backwards. Although the Ptolemaic system was long accepted, it did not completely explain the planetary movements which could be observed.

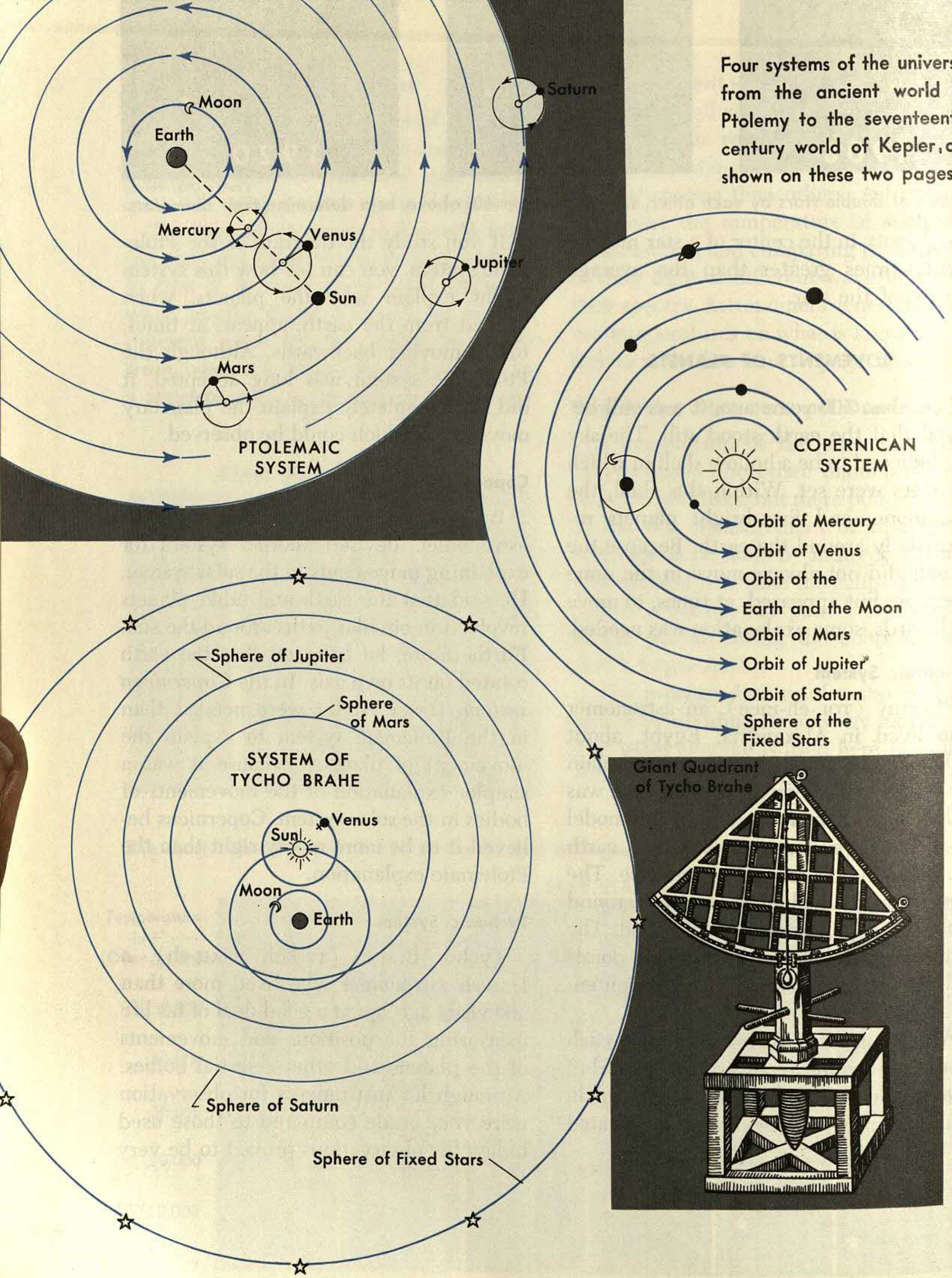
Copernican System

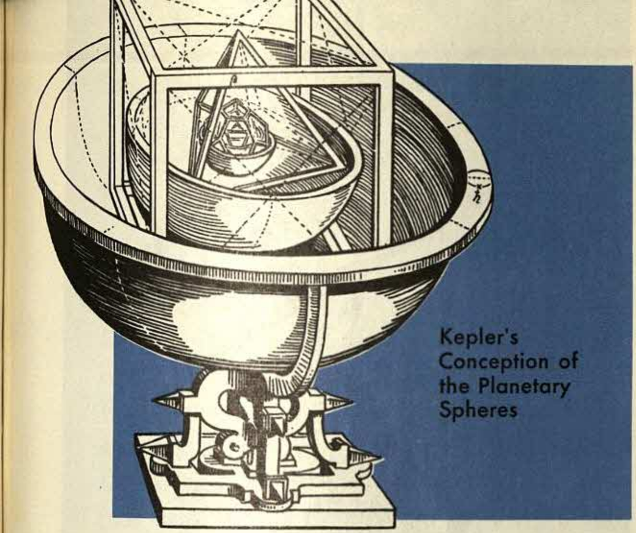
In 1543, Nicolaus Copernicus, a Polish astronomer, devised another system for explaining movements in the solar system. He said that the earth and other planets revolved in circular paths around the sun. Furthermore, he believed that the earth rotated on its own axis. In the ***Copernican system,*** fewer circles were needed than in the Ptolemaic system to explain the movement of planets. Because it was a simpler explanation of the movements of bodies in the solar system, Copernicus believed it to be more nearly right than the Ptolemaic explanation.

Tychonic System

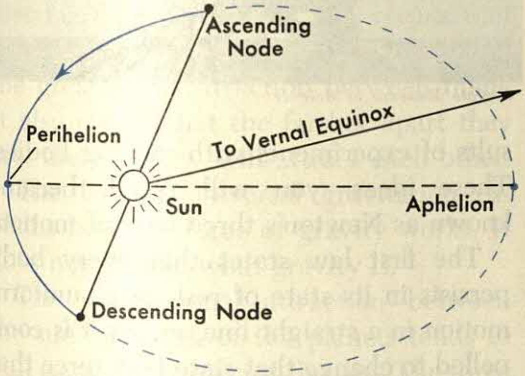
Tycho Brahe (TY-koh BRAH-eh), a Danish astronomer who lived more than 400 years ago, spent a good deal of his life measuring the positions and movements of the planets and other celestial bodies. Although his instruments for observation were very crude compared to those used today, his observations proved to be very

Four systems of the universe, from the ancient world of Ptolemy to the seventeenth-century world of Kepler, are shown on these two pages.



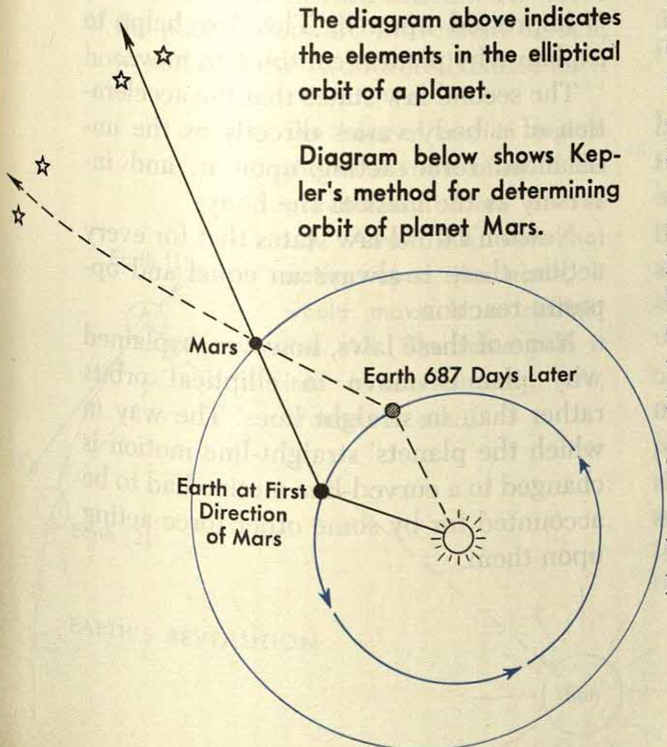


Kepler's Conception of the Planetary Spheres



The diagram above indicates the elements in the elliptical orbit of a planet.

Diagram below shows Kepler's method for determining orbit of planet Mars.



accurate. He set up the ***Tychonic system.*** It contained a central, fixed earth, around which the sun revolved. All the other planets revolved around the sun, as they did in the Copernican system. This system was short-lived. But Brahe kept a complete record of the observations on which he based it. This was very fortunate for those who followed him.

Kepler's Laws

During the last two years of Tycho Brahe's life, Johannes Kepler, a German astronomer, worked with him. When Brahe died, Kepler inherited Brahe's excellent records. As you will recall, Copernicus had said that the orbits of planets around the sun were perfect circles. When Kepler used Copernicus' explanation, he found that it did not fit many of Brahe's recorded observations. As a result of this observation, Kepler discovered a better explanation. He found that when ***ellipses,*** such as those shown in the diagram, were imagined as the shape of the planets' orbits around the sun, the observed movements of the planets could be explained. An ellipse is an oval-shaped geometric figure as shown at left.

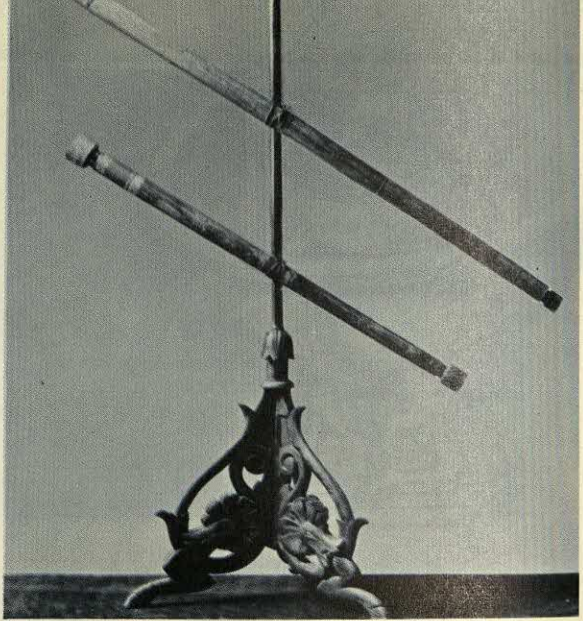
Kepler went on with his studies and developed three important laws which explained the movement of planets around the sun. The earth was, at first, not included. There was no way of explaining why the moon would not be left behind if the earth revolved around the sun.

Galileo's Observations

At about the time that Kepler was working on his studies of the orbits of planets, Galileo Galilei, an Italian, was

McMath-Hulbert Observatory of the University of Michigan

With telescopes similar to the ones at right, Galileo made discovery that planet Jupiter, above, had four bright moons revolving around it.



Buffalo Museum of Science

observing the sun, moon, and planets with a crude telescope which he had built. Among the things he discovered was that the planet Jupiter had four bright moons revolving around it. If Jupiter had moons revolving around it, the earth's moon must also be revolving around it. Kepler's explanations could now include the earth.

Newton's Three Laws of Motion

Once the movements of planets could be satisfactorily explained, attention was turned to finding an explanation of the forces that kept them moving. Galileo and others had experimented with the motions of bodies on earth and had made important discoveries.

As you will recall from Unit 3, Sir Isaac Newton, using all of the information available about the motion of solar bodies, set about to see if he could describe this motion. Review here the three ideas which he developed to describe the results of experiments with moving bodies. These ideas, you will recall, became known as Newton's three laws of motion.

The first law states that every body persists in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by a force that is impressed upon it. This law helps to explain why planets continue to move.

The second law states that the acceleration of a body varies directly as the unbalanced force acting upon it, and inversely as the mass of the body.

Newton's third law states that for every action, there is always an equal and opposite reaction.

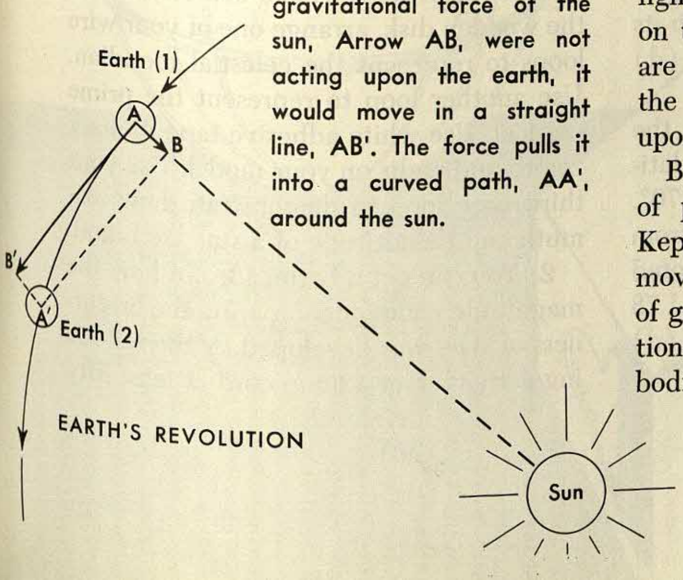
None of these laws, however, explained why planets move in elliptical orbits rather than in straight lines. The way in which the planets' straight-line motion is changed to a curved-line motion had to be accounted for by some other force acting upon them.

Law of Universal Gravitation

A legend states that Newton discovered the law of universal gravitation by being hit on the head by an apple. It was not so simple. Newton used Kepler's laws, his own laws of motion, and a great deal of mathematical thinking to discover the one law which explained all others—the law of universal gravitation. It states that every particle of matter in the universe attracts every other particle with a force that varies directly as the product of their masses and inversely as the square of the distance between them. This means that the greater the masses of the two bodies, the greater the attraction between them. It also means that the farther apart they are, the less they will attract each other.

The law of universal gravitation explains how the force of gravity works. It does not explain what gravity is.

The gravitational attraction between the sun and each of the planets tends to pull each planet toward the sun. The force of the planet's forward movement is such, however, that the two forces balance each other in such a way that each planet swings around the sun in a curved path.



The laws of motion explain the earth's revolution. If the gravitational force of the sun, Arrow AB, were not acting upon the earth, it would move in a straight line, AB'. The force pulls it into a curved path, AA', around the sun.

EARTH'S REVOLUTION

SUMMARY

Systems of measurement were devised to describe the movement and appearance of celestial bodies. Other systems were worked out to explain why they move and appear as they do. These systems have been developed by the creative imaginations of many scientists down through the ages.

Points on the earth and in the sky are located by using imaginary circles, or parts of circles. Positions along these circles are measured in degrees.

To indicate the great distances to stars, a new measuring unit, the light-year, was devised. The powers-of-ten system for noting numbers is used by astronomers to make it easier to work with the large numbers involved in measuring in space. Astronomers can also use the mathematics of trigonometry to compute the distance from the earth to celestial bodies.

The brightness of a star is measured by comparing it with other stars. Star temperatures, inferred by analyzing the light from stars, are generally reported on the Kelvin scale. The masses of stars are computed from their luminosity and the effects of the gravity of other stars upon them.

By using the records of the movements of planets kept by other astronomers, Kepler developed laws to explain these movements. Newton's laws of motion and of gravitation also help to explain the motions of the planets and other celestial bodies of the universe.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. From the beginning of man's interest in the celestial bodies, he has not only described them, but he has also attempted to (a) control them (b) regulate them (c) explain them (d) destroy them.

2. Positions are located north and south on the earth by using (a) parallels of latitude (b) meridians of longitude (c) nadir (d) zenith.

3. The celestial sphere is (a) a crystal globe to which the stars are attached (b) a globe of the earth (c) the circular distance from pole to pole (d) an imaginary sphere extending an unlimited distance into space.

4. Halfway between zenith and nadir is an imaginary circle called the (a) celestial equator (b) horizon (c) latitude (d) longitude.

5. A star in azimuth 180° and altitude 30° would be one-third of the way from horizon to zenith in the (a) northern sky (b) southern sky (c) eastern sky (d) western sky.

6. The magnitude of a star refers to its (a) size (b) color (c) temperature (d) brightness.

7. Two-thirds of the distance from the equator to the North Pole is north latitude (a) 15° (b) 60° (c) 180° (d) 70°.

8. Uranus is 1,780,000,000 miles from the earth. This number would be noted in the powers-of-ten system as (a) 1.78×10^9 (b) 17.8×10^9 (c) 178×10^9 (d) $.178 \times 10^9$.

9. The mathematics that deals with the relation between angles of right triangles and their sides is called (a) algebra (b) astronomy (c) trigonometry (d) geometry.

10. The universal law of gravitation states that the greater the masses of two bodies the (a) farther apart they are (b) nearer they are to each other (c) less is the attraction between them (d) greater is the attraction between them.

B. Building Models to Test Ideas

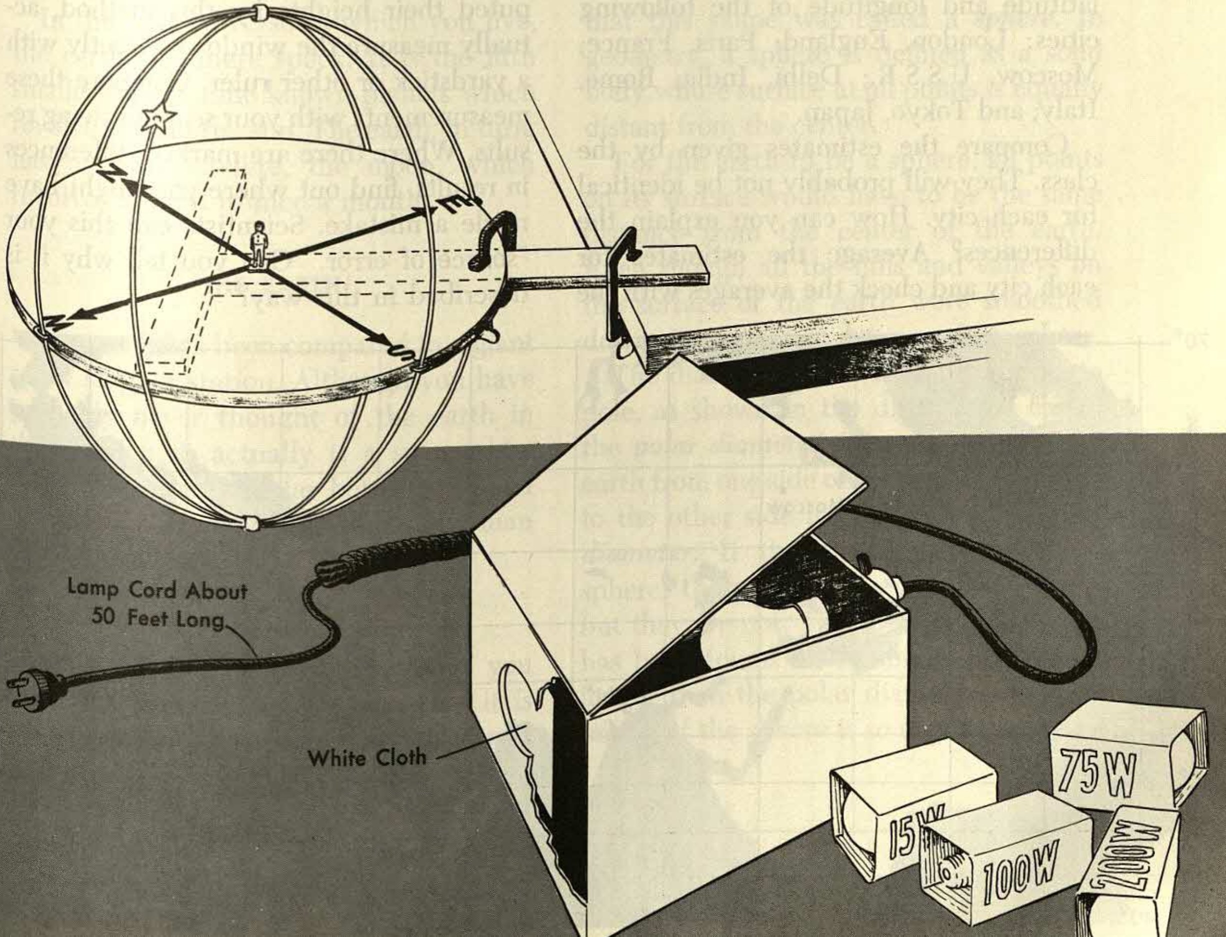
1. Make a model of the celestial sphere. Use a circular, thin wood disk about two feet in diameter to represent the surface of the earth. Attach a small, toy-like figure of a person to the center of the disk in such a way that the figure can be turned around. This figure represents the observer. The outer edge, or circumference, of the wooden disk represents the celestial horizon of the observer. Mark points north, south, east, and west on the celestial horizon. Make three circular loops of heavy wire. Each loop should be just large enough to fit snugly around the edge of your wooden disk. While someone holds the wooden disk, arrange one of your wire loops to represent the celestial meridian. Use another loop to represent the prime vertical. Use white adhesive tape to mark zenith and nadir on your model. Use your third wire loop to demonstrate how azimuth and the altitude of a star are found.

2. You can get a better idea of how the magnitude scale for comparing the brightness of stars was developed by the following activity. Get a lamp cord at least fifty

feet long and electric lamps with ratings of 15, 40, 75, 100, 150, and 200 watts. Obtain an empty cardboard box about one foot square. Cut a hole in one side of it so that the lamp socket on the cord will fit into it tightly. Cut a circular hole about three inches in diameter in the side of the box opposite the opening. Paste a thin piece of white cloth over this hole.

After dark, have someone take the box as far away from your house as the length of the lamp cord will permit. The box should be placed so that the cloth-covered opening is facing you. While you stand outside your house and observe, have someone put each of the lamp bulbs into the socket in the box in the order of their brightness. As each is lighted, note the difference in brightness. Have each bulb lighted a number of times so that you become thoroughly familiar with its brightness. Now have the bulbs inserted into the socket at random without any regard to brightness. See if you can now tell the wattage of each lamp being used by observing the brightness of the light that comes from the box. It would be better, of course, if you could have two complete setups so that you could use one box as a standard of comparison.

3. The Ptolemaic system for explaining why planets appear, at times, to be traveling backwards, is described on page 277. By using the diagram on page 278, see if you can make a model of Mars to demonstrate how the system worked.



C. Recalling Experiences With Motion

These questions may help you to understand better how the rotation of the earth from west to east makes the stars appear to move from east to west across the night sky.

1. In what direction do telephone poles appear to be moving when you view them from the window of a fast-moving train or automobile?

2. When you take off in an airplane, in what direction does the ground appear to be moving?

3. When you ride on a merry-go-round, in what direction do objects around you appear to be moving?

D. Using What You Have Learned

After studying a map or globe, each member of the class should estimate the latitude and longitude of the following cities: London, England; Paris, France; Moscow, U.S.S.R.; Delhi, India; Rome, Italy; and Tokyo, Japan.

Compare the estimates given by the class. They will probably not be identical for each city. How can you explain the differences? Average the estimates for each city and check the averages with the latitudes and longitudes given for these places in a good atlas or encyclopedia.

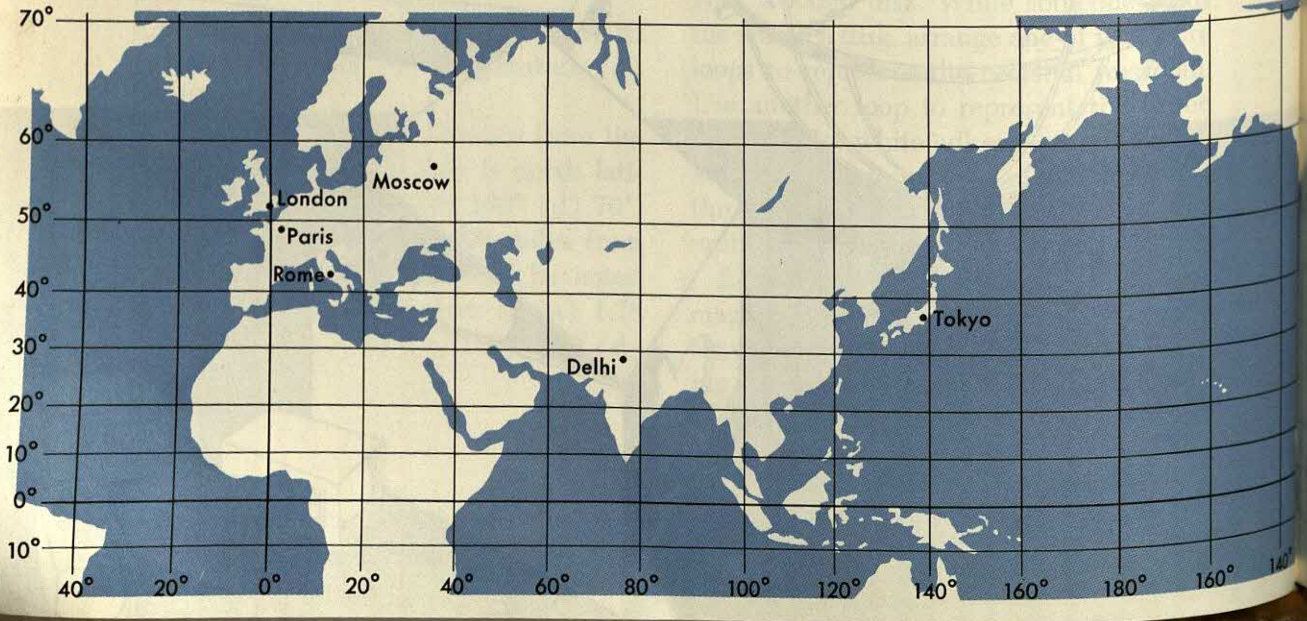
2. Write the numbers in the following sentences by using the powers-of-ten notation system.

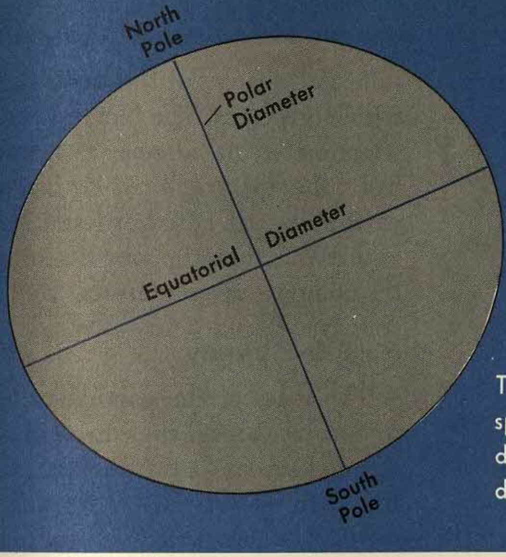
a. One pound of hydrogen, on changing to helium, liberates energy equal to the burning of about 20,000,000 pounds of coal.

b. Some stars are nearly 600,000 times brighter than the sun. However, there are other stars that are only .0000018 as bright as the sun.

c. Sirius, the brightest of the stars, is about 50,000,000,000,000 miles from the earth.

3. By using the scale-drawing system described on page 273, compute the height of windows on different floors of your school or your home. After you have computed their heights by this method, actually measure the windows directly with a yardstick or other ruler. Compare these measurements with your scale-drawing results. Where there are marked differences in results, find out where you might have made a mistake. Scientists call this your "source of error." Can you tell why it is described in this way?





The earth is not a true sphere but an oblate spheroid with unequal diameters. Its equatorial diameter is thirty miles longer than its polar diameter.

PROBLEM 2: WHAT HAS BEEN LEARNED ABOUT THE EARTH AND OTHER MEMBERS OF THE SOLAR FAMILY?

In the vast universe in which you live, the earth is a mere speck. It is the fifth smallest of the nine known planets which revolve around the sun. The earth, in turn, has its own satellite, the moon, which revolves around it once a month.

THE EARTH

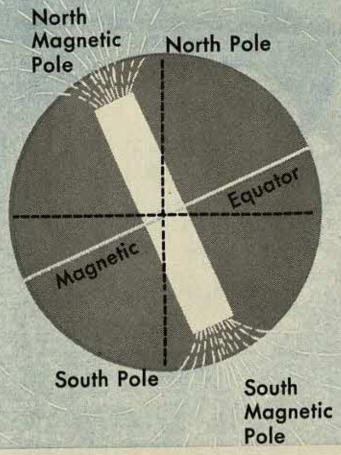
The earth has been compared to a giant space ship, or station. Although you have probably never thought of the earth in this fashion, it actually is a space ship. And it is larger, and far better equipped to support human life, than any man could build.

Size and Shape

In school, one of the first things you were told about the earth was that it is shaped like a huge ball. Later you learned that this shape was called a ***sphere.*** In geometry, a sphere is defined as a solid body whose surface at all points is equally distant from the center.

For the earth to be a sphere, all points on its surface would have to be the same distance from the center of the earth. Even though all the hills and valleys on the surface of the earth were smoothed down, it would not be a perfect sphere.

The diameter of the earth from pole to pole, as shown in the diagram, is called the ***polar diameter.*** The diameter of the earth from one side of the equator through to the other side is called the ***equatorial diameter.*** If the earth were a perfect sphere, these diameters would be equal, but they are not. The equatorial diameter has been found to be about thirty miles longer than the polar diameter. The flattening of the sphere is so slight that on an



The axis of the earth's magnetic field is inclined to the axis of the rotation of the earth.

eighteen-inch globe, the polar diameter is only 1⁄16 of an inch shorter than the equatorial diameter. Hence, even though the difference between diameters is slight, scientists cannot accurately call the globe a sphere. Astronomers have described the earth more exactly as an ***oblate spheroid.*** The word oblate means flattened at the poles. Spheroid means nearly the shape of a sphere.

IGY scientists, on the basis of information they gathered, are inclined to think that the earth may be pear-shaped.

Magnetic Field

You probably have had the experience of sprinkling iron filings on a sheet of paper or glass plate laid over a bar magnet. The filings arrange themselves in a pattern such as that shown in the diagram on page 156. This pattern shows that there is a field of force around the magnet.

The earth acts as though it had a huge bar magnet running through its center. The magnetic poles of the earth, as in the diagram above, are not in the same positions as the poles of the earth's axis around which it rotates. The North Magnetic Pole is estimated to be several hundred miles from the geographic North Pole of the earth's axis. It is toward the North Magnetic Pole that the north-seeking end of the compass needle points.

Mass and Density

The mass of the earth has been determined by careful measurements of gravitational forces at the surface. It has been found to be 6.6×10^{21} tons. As you will recall, you can write this number by putting twenty zeroes after 66.

The density of the earth is 5.52 times the density of water. This high density is accounted for by assuming that the core of the earth is composed mainly of iron and nickel such as are found in most large meteorites.

The pressures near the center of the earth are around fifty million pounds per square inch. This is roughly three million times the pressure of the atmosphere at sea level. The mass of the earth's atmosphere, which will be discussed in a later unit, is less than one-millionth the mass of the earth itself.

Rotation of Earth

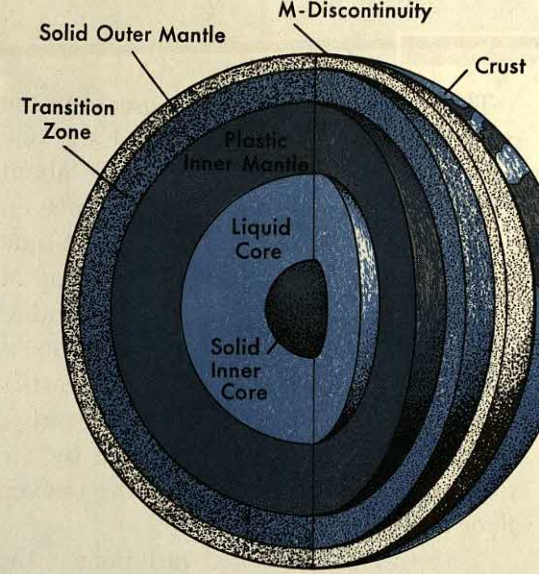
As recently as 550 years ago, people believed that the earth stood still. Around that time, Copernicus came up with the idea that the earth not only revolved around the sun, but also rotated on its own axis. He had no evidence that this was true. It just seemed more reasonable to him that a small planet such as the earth should turn rather than the huge celestial sphere of the sun.

As you will learn in the next unit, the shifting of north and south winds toward the east and west is one bit of evidence that the earth rotates. There are still other kinds of evidence which you will learn about if you continue your study of science into high school physics.

If you should whirl a rubber ball which has been securely attached to a string, you would note a tendency of the ball to escape, or pull away, from the string. This tendency is called the ***centrifugal effect.*** It is an effect characteristic of all whirling bodies. Because of the earth's rotation, all parts of it tend to move out from its axis. This tendency is greatest at the equator and least at the poles. This explains why the earth bulges slightly more at the equator than it does at the North and South Poles.

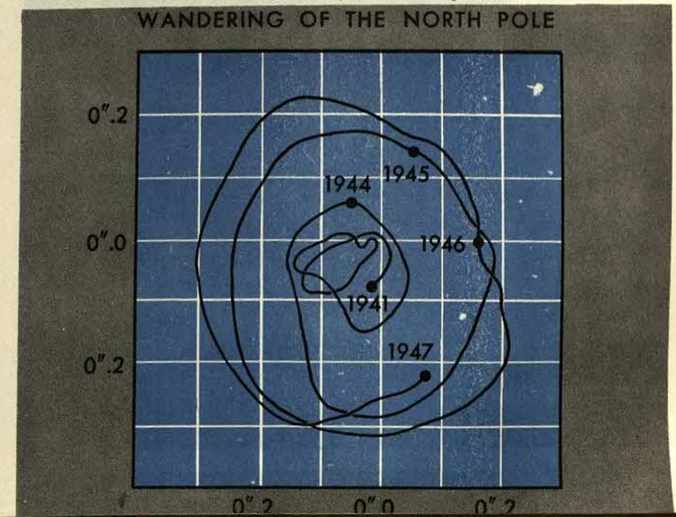
From measurements that have been carefully made over a long period of time, it is clear that the North and South Poles do not remain in the same place. As you will see from the diagram in column 2, they appear to shift positions as much as twenty feet in one year. This is explained as a shifting of the earth's surface with respect to its axis.

The period of the earth's rotation has been used as a master clock for timing events both on earth and in the celestial sphere. To serve as a completely accurate clock, there should be no differences in its period of rotation from year to year. However, when the period of the earth's rotation has been compared with other celestial events such as the revolution of other planets, the earth's moon, and the moons of Jupiter, slight variations have been noted by astronomers.



Depth in Kilometers	Composition	Density
	Silicates	2.5-3.4
410	Granite Basalt (Solid)	
1,000		
2,900	Much Iron (Solid)	5.5
	Nickel-Iron (Molten)	9.5-12
5,120	Nickel-Iron (Solid)	14.5-18
6,370		

The North Pole is a wanderer, which follows a complex path over the earth's surface. Its position is shown at the beginning of each year.



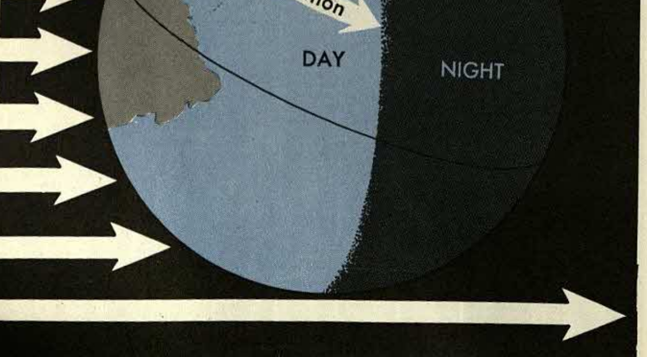
There has been a steady increase in the period of the earth's rotation. Each one hundred years the earth takes about 0.0016 of a second longer to turn once on its axis. If a clock which kept perfect time had been set 2,000 years ago, today it would now be running about three-and-a-quarter hours fast, compared with clocks set with the present period of the earth's rotation. This slowing down of the earth's rotation is believed to be caused by the friction of ocean tides against the uneven floor of the ocean.

There are also seasonal variations in the earth's rotation, believed to be caused by the seasonal movement of air masses over the earth. Still other variations occur for which astronomers have been unable to account. All in all, these variations make the rotation of the earth less reliable as a timekeeper than it was thought to be.

Day and Night

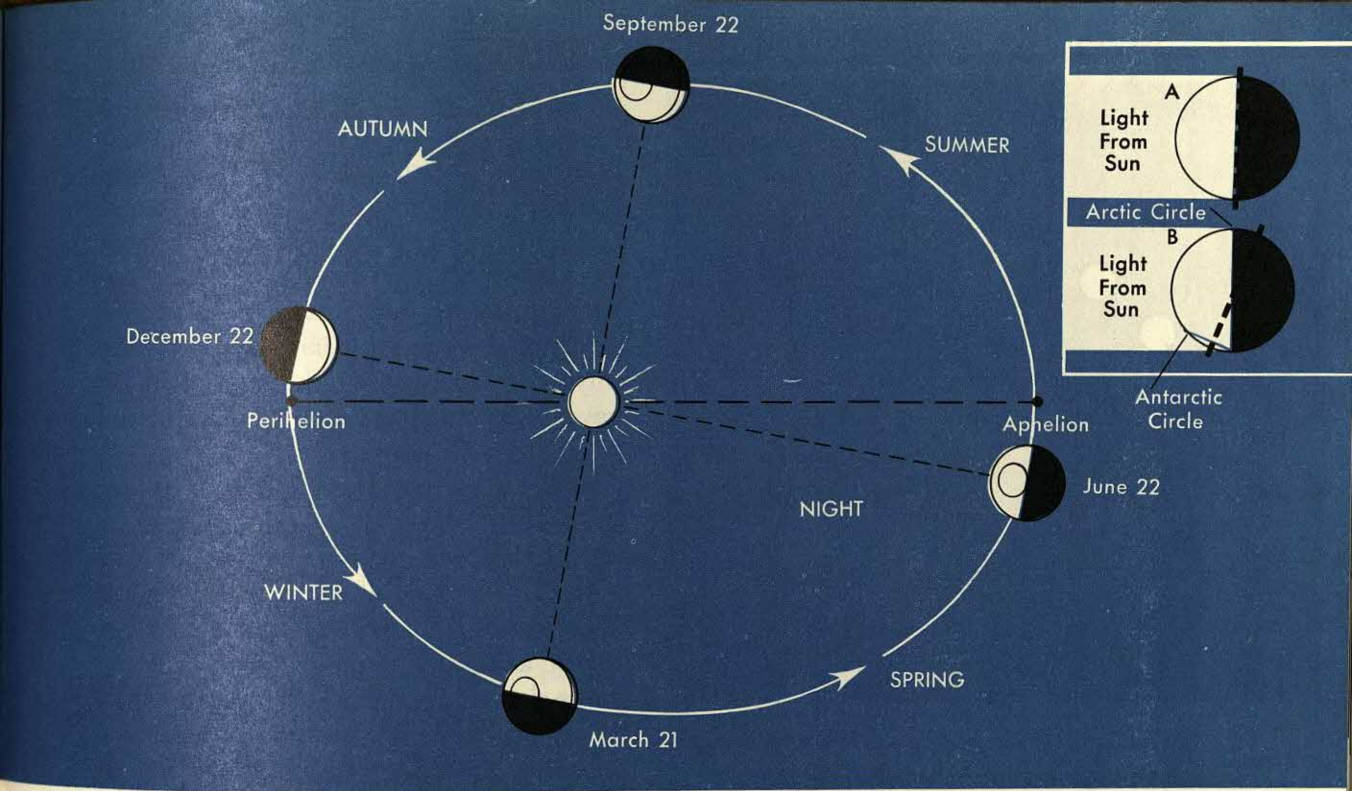
As you know, day and night are caused by the rotation of the earth. You might think that any place on the earth would be lighted for half the time and dark for the other half while the earth makes one complete turn. If this were true, every spot on the earth would have daylight for twelve hours and darkness for twelve hours; that is, day and night would be of the same length. You know, however, that the length of day and of night changes throughout the year. On only two days is it the same everywhere on the earth. What accounts for these differences?

Rotation of earth on its axis every twenty-four hours is responsible for day and night.



If, while the earth rotated on its axis, it were in the position shown in A of the diagram on page 289, the periods of light and darkness each day would be the same everywhere on the earth. Actually, the earth's axis is tilted at an angle, as shown in B. By comparing these two positions, you can see that the axis on which the earth rotates every twenty-four hours is not vertical but is tilted 23½ degrees. It remains tilted at this same angle as the earth revolves around the sun. This tilting causes the length of day and night to change throughout the year and to be different for different parts of the earth as the earth revolves in its orbit around the sun. See diagram on page 289.

Note the position of the earth on December 22. On that date, the length of daylight and of darkness varies greatly at different places on the earth. While the earth is at this position in its orbit, the area within 23½ degrees of the North Pole is not touched by the sun's rays and is, therefore, dark for twenty-four hours each day. The area is bounded by an imaginary line called the ***Arctic Circle.*** During the same period, the area within 23½ degrees of the South Pole, within the ***Antarctic Circle,*** is lighted continuously by the sun's



If the earth's axis were in a vertical position, shown by dotted line in A, length of day and night would be the same at all places on the earth. But the earth's axis is tilted 23½ degrees from the vertical, as shown in B. This accounts for changes in length of day and night and seasonal changes.

rays. Places within this imaginary line have, therefore, twenty-four hours of daylight while those within the Arctic Circle are in darkness.

By March 21, the earth, in its journey around the sun, has moved to the position shown on this page. When the earth is in this position, the sun's rays strike it from the North Pole to the South Pole. On March 21, therefore, every place on the earth has twelve hours of daylight and twelve hours of darkness.

On June 22, the earth reaches the position shown on this page. Now the entire area within the Arctic Circle is lighted, while the area within the Antarctic Circle is in darkness. This is the condition opposite to that which existed December 22.

The position of the earth on September 22 is such that it is lighted by the sun as it is on March 21. There are again twelve hours of daylight and darkness each day.

The steady movement of the earth around the sun and the tilting of the earth's axis produce gradual changes during the year in length of day and night.

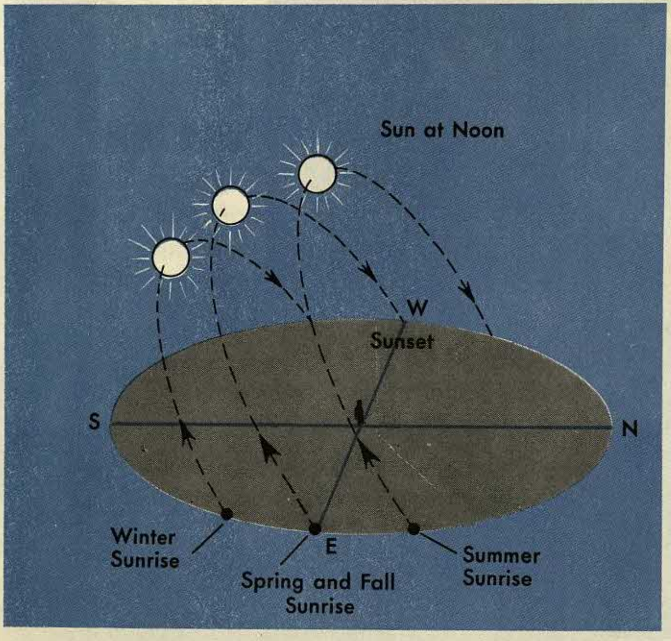
Seasons of the Year

The seasons also are explained by the fact that the axis on which the earth rotates every twenty-four hours remains tilted at the same angle while the earth revolves in its orbit around the sun every 365 days. As you can see, the northern end of the axis is tipped away from the sun on December 22. On this date, the sun appears to be farther south, at all points north of the equator, than it does during any other time during the year. And the rays of sunlight that reach these points are more slanted than at any other time.

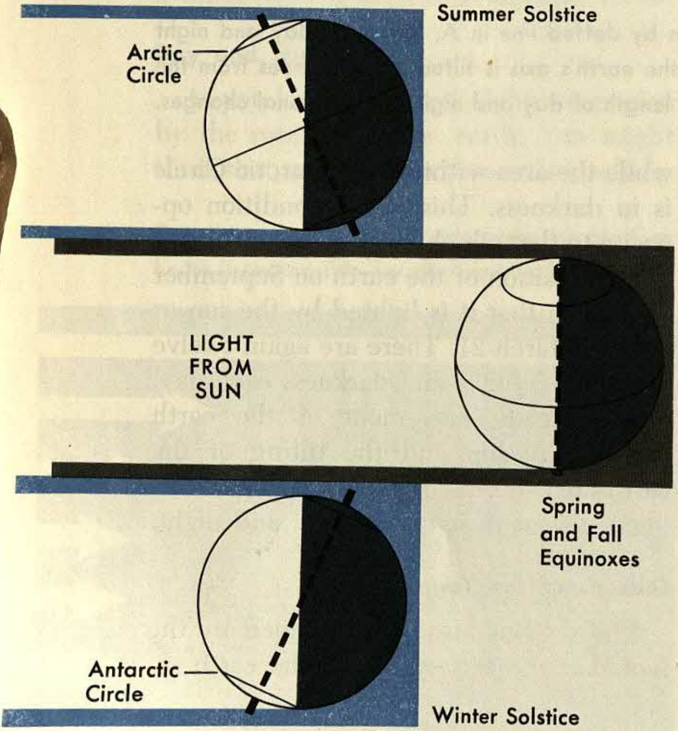
When rays from the sun are slanted (see at left), they cover a larger surface of the earth. Consequently they do not have so great a heating effect as they do when they strike the earth directly. The farther north a place is from the equator, the more slanted are the rays of sun that strike it on December 22, the shorter the days, and the lower the temperatures. For all places north of the equator, this is the winter season. December 22 is called the ***winter solstice.*** Solstice comes from two Latin words—*"sol"* for sun and *"sistere,"* to make stand still. The sun seems to stand still because it remains at the nearly southernmost point of its apparent travels in the sky for several days in succession.

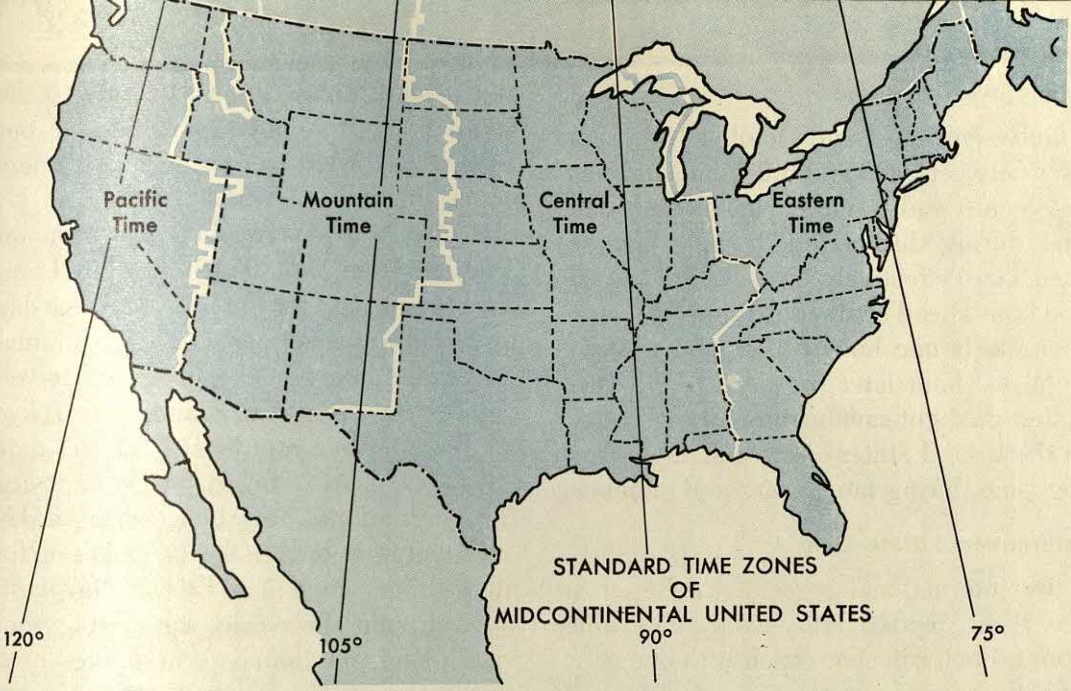
March 21 is called the ***spring equinox.*** Equinox comes from the Latin *"aequus,"* meaning equal and *"nox,"* meaning night. It ushers in the mild spring season. September 22 is called the ***autumnal equinox*** and introduces the fall season.

June 22 is called the ***summer solstice.*** On that date, because the North Pole tips toward the sun, that part of the earth north of the equator, or the ***Northern Hemisphere,*** has its longest day and shortest night. The sun's rays that reach the Northern Hemisphere at this time are less



In summer, there are more hours of sunlight each day, and sun is higher in sky at noon.





slanted, the days are warm. On the same date, rays that strike the part of the earth south of the equator, or the ***Southern Hemisphere,*** are very slanted. The days, therefore, are cold. The Southern Hemisphere has its winter while the Northern Hemisphere has its summer.

Time Zones

The earth turns from west to east. The sun, therefore, appears to rise in the east. The farther east you live, the earlier you see the sun. As the earth continues to rotate eastward during the day, the sun seems to move westward across the sky.

The time of day when sun is at its highest position in the sky is called ***noon.*** Clocks and watches are set at noon, or 12 o'clock. If everywhere on the earth clocks were set to show 12 o'clock when the sun was nearest the center of the sky at any particular place, there would be so many different times it would be very confusing.

Four standard time belts, or zones, have been established in midcontinental United States to avoid such confusion and inconvenience. All clocks within each zone show 12 o'clock at the same time, regardless of the sun's position. For example, Boston, Massachusetts, Buffalo, New York, and Detroit, Michigan, have the same clock reading although the sun rises earlier in the easternmost city. As you will see in the diagram, the four standard time zones in midcontinental United States are Eastern, Central, Mountain, and Pacific. There is an hour's difference in time between zones. When it is 4 a.m. in the Eastern standard time zone, it is 3 a.m. in the Central zone, 2 a.m. in the Mountain zone, and 1 a.m. in the Pacific zone.

Daylight-Saving Time

Between May 1 and October 1, the sun rises between 4:30 and 6:00 a.m., and sets between 6 and 8 p.m. It has been found that during this period daylight can be used more effectively if clocks are turned one hour ahead of standard time. The day then starts one hour earlier and it stays light one hour later by the clock. This is called daylight-saving time. Many places in the United States observe daylight-saving time during late spring and summer.

International Date Line

By international agreement, the earth has been divided into twenty-four time zones. Each zone corresponds to one hour of difference in sun time. For instance, if you were to start from Chicago and travel westward around the earth, you would have to turn your watch back one hour as you entered each time zone. In other words, you would gain one hour by clock in each zone. By the time you had completed your journey around the earth and had turned back your watch an hour for each time zone you entered, you would have gained twenty-four hours, or one day. If you were to travel eastward around the world, you would turn your watch ahead one hour as you entered each zone and would lose twenty-four hours. It would be impractical to change the calendar wherever you happened to be.

In 1884, an international conference established a definite line on the earth's surface, along which the date is advanced, or set back, one day, depending upon the direction of travel. This is called the international date line, as you learned in Problem 1. It is located in the Pacific Ocean and extends from the North Pole to the South Pole. It is not a straight line but zigzags in order to avoid crossing any important body of land.

If you started traveling eastward on Tuesday from, say, Tokyo to San Francisco, you would set the date back one day to Monday as you crossed the international date line. But if you started traveling westward from San Francisco to Tokyo on Wednesday, you would set the date ahead one day to Thursday as you crossed the international date line. Losing a day at the international date line makes up for all the hours you gained by traveling westward around the world and setting your watch back one hour as you entered each of the twenty-four time zones. Likewise, gaining a day at the international date line as you travel eastward makes up for the hours you lost when you set your watch ahead one hour at each of the twenty-four time zones.

The Earth From Other Planets

Pictures of the earth taken from rockets more than a hundred miles from the surface of the earth give some idea of what the earth might look like when viewed from other planets. It would be seen only by reflected light from the sun, as are other planets. From Venus, it would be the brightest object in the night sky. Through a telescope, it would appear as a disk. Its surface would not be seen clearly through its brilliantly lighted atmosphere. Through breaks in the clouds, however, an observer might get an occasional faint glimpse of the earth's surface. Such an observer might see the ice and snow as white caps at either pole.

American Museum of Natural History

The earth, as seen from other planets, might appear somewhat as shown in this painting.

Distance to the Sun

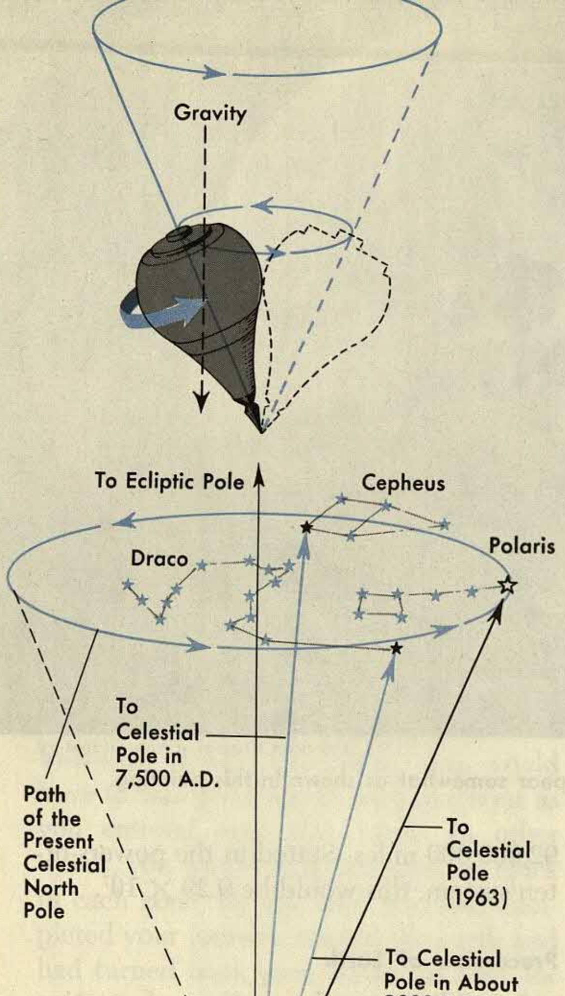
Since the earth's orbit around the sun is an ellipse, its distance from the sun at different times of the year is not the same. The position in the earth's orbit where it is nearest the sun is called the ***perihelion,*** as you can see in the diagram on page 289. *"Peri"* means around and *"helios"* means sun. The position of the earth when it is farthest from the sun is called ***aphelion.*** This term is derived from the Greek word *"apo,"* meaning away from, and *"helios,"* meaning sun.

When the distance from the earth to the sun is given, it is usually stated as ***mean distance.*** Mean distance is the average between the least and the greatest distance to the sun. The mean distance from the earth to the sun is considered to be 92,900,000 miles. Stated in the powers-of-ten system, this would be 9.29×10^7.

Precession of Earth

In addition to the motions of rotation and revolution, the earth has a third motion. To show this, you can use a spinning top. You probably have noticed that when a top begins to slow down, it wobbles. Because of its wobble, an imaginary line extending through its axis of rotation would form a circle like the one shown in the diagram on page 294.

The gravitational pull of the moon on the equatorial bulge causes the earth to wobble in the same way. The end of an imaginary line drawn from the North Pole of the earth into the celestial sphere would also form a circle. It takes about 26,000


Gravity
To Ecliptic Pole
Cepheus
Draco
Polaris
To Celestial Pole in 7,500 A.D.
Path of the Present Celestial North Pole
To Celestial Pole (1963)
To Celestial Pole in About 3000 B.C.
Moon

EARTH'S PRECESSIONAL MOTION

The earth not only rotates and revolves, but it also wobbles, much like a spinning top. This third motion, called precession, is caused by the pull of the moon on the earth. Precession is responsible for the wandering of the Pole Star.

years for the earth to complete one wobble. Because the North Pole of the earth now points to ***Polaris,*** it is called the Pole Star. However, 3,000 years ago another star, ***Alpha Draconis,*** or ***Draco,*** was the Pole Star. ***Vega,*** in the constellation ***Lyra,*** will be the Pole Star 12,000 years from now. This wobbling motion of the earth is called ***precession.***

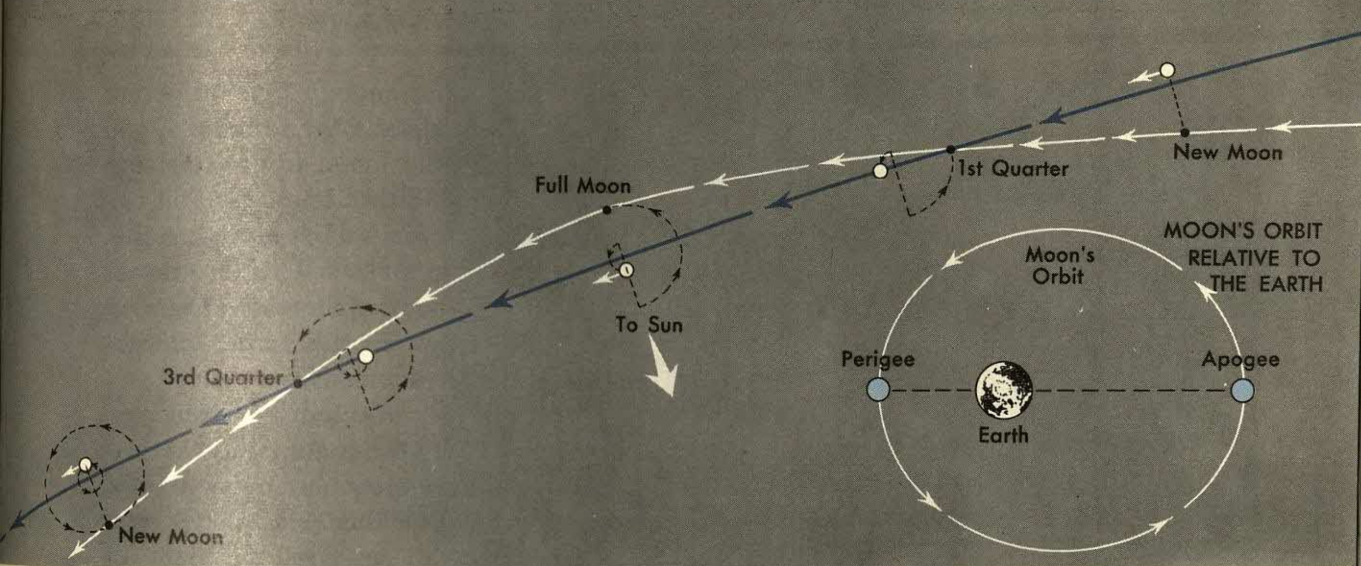
THE MOON

The moon ranks sixth in size among the thirty-one satellites in the solar system. Its diameter is 2,160 miles, about one-fourth of the diameter of the earth. Although the diameter of the sun is about 400 times greater than that of the moon, they appear to be approximately the same size when viewed from the earth. This is because the sun is about 400 times farther from the earth. The volume of the moon is only $\frac{1}{50}$ that of the earth, its mass $\frac{1}{82}$, and its gravitational force is only $\frac{1}{6}$.

Movements of the Moon

The moon's revolution may be considered in two ways. The moon makes one revolution around the sun each year as it accompanies the earth. It also makes a monthly revolution around the earth in an elliptical orbit, as shown in the diagram on page 295.

The point on its orbit where the moon is nearest to the earth is called the *perigee.* The Greek word *"peri"* for around is combined with the Greek word *"ge"* for earth. *Apogee,* the farthest point from the earth reached by the moon, is a combination of the Greek word *"apo,"* meaning from, with "ge" for earth. As you may recall,



these terms are also used in describing the orbits of artificial earth satellites. The moon, as you can see from the diagram on this page, weaves in and out around the earth. However, the moon's orbit is always curved away from the sun.

The distance from the earth to the moon may be as little as 221,463 miles at perigee and as great as 252,710 miles at apogee. The average distance is about 239,000 miles. The moon, figured at the speed of light (186,000 miles per second), is 1.28 light seconds from the earth.

In 1946, an experiment was performed in which radar waves were directed at the moon at regular intervals. As you know, radio waves travel at about 186,000 miles per second. It took 2.56 seconds for the radar beams to go from the earth to the moon, bounce off, and return to the earth. This was not an important discovery because the distance to the moon had already been determined more exactly in other ways. However, it was the first actual experiment performed in astronomy. Can you tell why it was an experiment?

Moon Rise

You see the moon by sunlight which it reflects to earth. Because of the earth's rotation from west to east, you see the moon rise in the east and set in the west. You probably have noticed, however, that the moon rises later each night. In fact, it rises about forty-eight minutes later each night. Why does this happen? It is accounted for by the revolution of the moon around the earth. In one complete revolution around the earth, the moon moves an angular distance of 360°. It moves this distance in twenty-nine days—a lunar month. In one day, therefore, it moves about 12° farther east in its orbit. Now the earth turns once around, or 360°, in twenty-four hours. In one hour, therefore, it turns 15° toward the east. Thus it takes the earth almost one hour longer each day to turn to where the moon can be seen in its new position. In fact, it takes $\frac{12}{15}$ of an hour, or about forty-eight minutes longer. This accounts for the rising of the moon forty-eight minutes later each night. Can you explain now why, during certain periods of the month, you do not see the moon at night?

Phases of the Moon

During a lunar month, the shape of the moon appears to change. These different shapes are called ***phases.*** The phases of the moon are called new, crescent, quarter, gibbous, and full.

The phases of the moon can be explained by two facts. In the first place, only one half of the moon is ever lighted by the sun at any one time. In the second place, the moon is viewed at different positions in its orbit during a lunar month. An examination of the diagram on this page will help you to understand how these two facts explain the moon's phases.

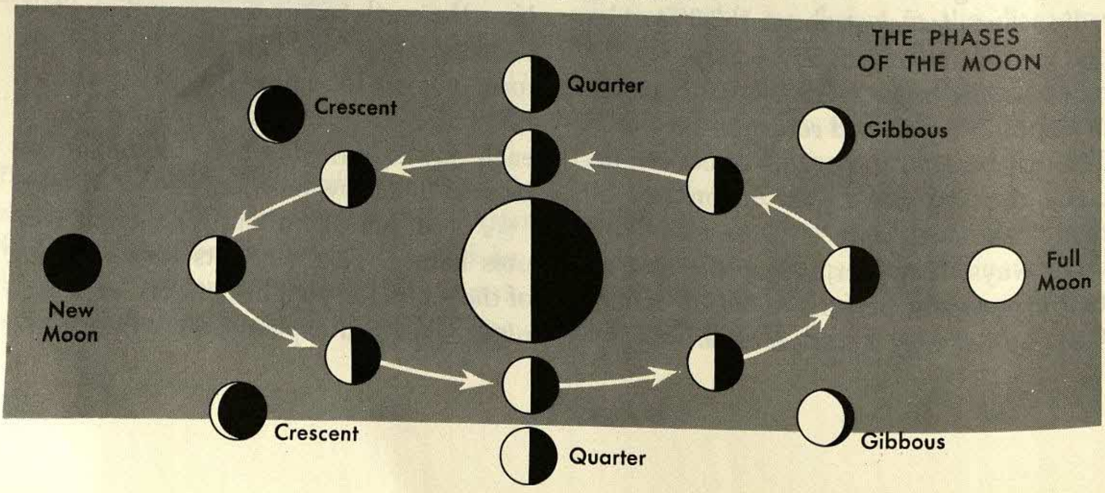
Close-Up of the Moon

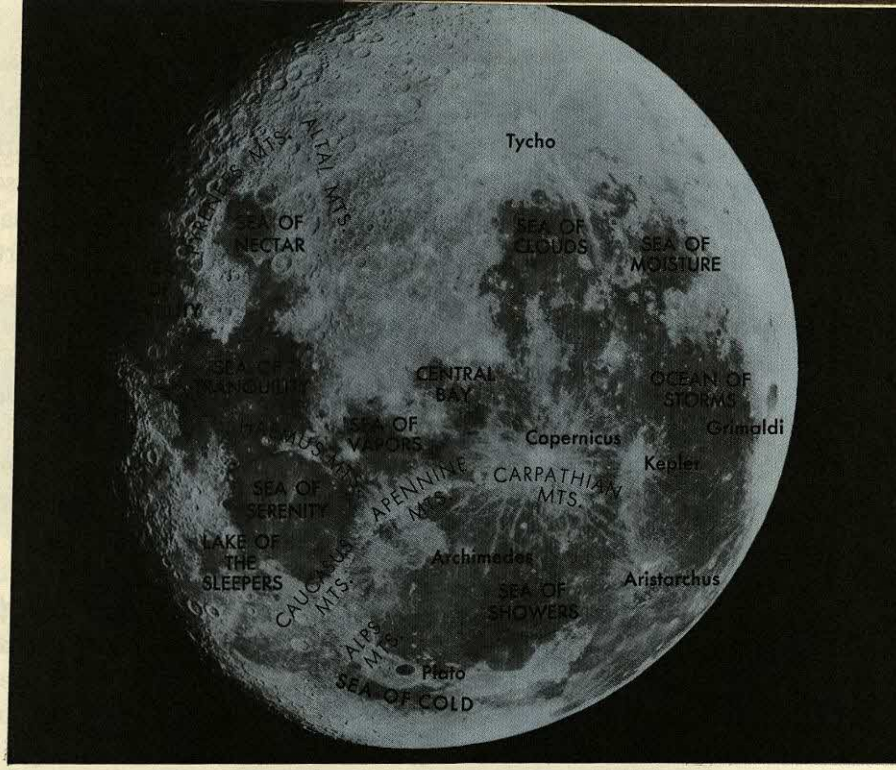
What is it like on the moon? This is a question that interests an increasing number of people as rocket trips to the moon become more nearly a possibility. By using their telescopes, astronomers have been able to find out almost as much about the moon as they would by making a rocket trip to it. A small, but good quality, telescope can gather enough light to permit seeing surface details the same as if you were viewing the moon from a distance of 2,000 miles. With a telescope that collects about four times more light than this, an observer can make out surface details as if he were viewing the moon from less than 1,000 miles. In this sense, the telescope is the astronomer's space ship.

The evidence collected by astronomers in the past led to the conclusion that there was no atmosphere on the moon. They collected much of this evidence by using spectroscopes to analyze the light reflected from the moon. They also observed that when stars, or other bodies disappear behind the moon, their light does not become dimmer before they disappear completely. Could this be used as evidence that the moon has no atmosphere? How?

Scientists at Cambridge University recently reported that stellar radio waves passing the moon appear to be as disturbed as they would be if they were passing through an atmospheric density equal to 10^{-13} of that of the earth. It may be that the moon has an extremely thin atmosphere.

Phases of the moon are shown below. As the moon moves around the earth, one half of it is always lighted by the sun. You see the lighted half during full moon.





Most of the geographical features of the moon have been given names. Craters carry the names of famous scientists, principally astronomers. Names of mountain ranges have been borrowed from those on the earth. "Sea" names are fanciful.

Lick Observatory

Surface of the Moon

Astronomers have obtained so much information about the surface of the moon that it has been possible to prepare maps of it such as the one shown at the top of this page.

The height of mountains and the width and depth of moon craters have been measured quite accurately. Some of the mountain peaks have elevations of 26,000 feet—almost as high as Mount Everest. More than 30,000 craters have been located, some of them 150 miles in diameter.

Although the rocky surface of the moon has not been weathered by rain or wind, there have been other forces to break it up. When the noon sun is overhead on the moon, the surface temperature on the moon is 100°C; at midnight, it is −150°C. These marked changes in temperature crack the rocky surfaces and break off rocks of different sizes. The moon is hit with meteorites which also help wear away its surface.

Evidence having to do with sudden changes in the surface temperature of the moon during an eclipse has led to the conclusion that the moon is covered with a very fine dust. Some believe that the dust is only a few inches thick, while others believe it may be many feet thick. The final answer may not be known until a space craft is sent to the moon.

Origin of the Moon

Many efforts have been made to find out how the moon came to be as it is today. Scientists have used what they know about the earth, moon, and other bodies in the solar system and then imagined what kind of process could have produced such bodies.

One idea which is favored by some scientists is that the earth and the moon were separated from a larger, very hot, fluid body that was rotating so fast it could not hold itself together.

Because the earth contained more than fifty times as much material as the moon, it cooled more slowly and developed an atmosphere. As it cooled, the earth gradually formed a solid crust. The hot material beneath the crust pushed up mountains and formed craters. The mountains were worn away and the craters filled by some agents of weathering, such as wind or rain. Through the ages, still other mountains were uplifted and the weathering continued. Weathering took place because the earth has an atmosphere.

The moon, being much smaller than the earth, cooled more rapidly. As it cooled, it, too, probably formed an atmosphere. But its gravitational force was only 1/6 that of the earth. This force was not enough to hold the molecules of gas making up its atmosphere, and they escaped into space. Without an atmosphere, the mountains and craters formed by the action of hot materials beneath its crust were not leveled away but remained pretty much as they were after the upheaval of this material. Another explanation states that the craters were probably formed by meteorites hitting the moon when it was still a hot body. It may be that both actions took place.

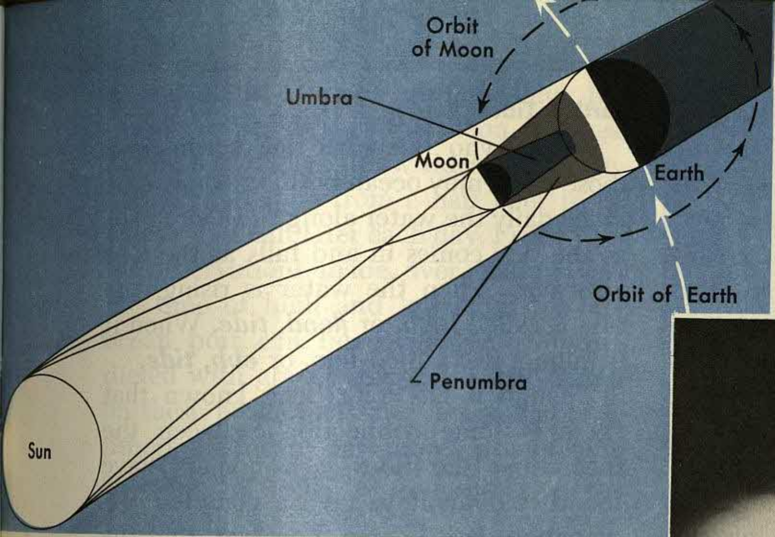
Future Explorations

The evidence which scientists have collected in their efforts to describe and explain the moon have been gathered from only one side of it. You see only one side of the moon because the time it takes the moon to make a complete rotation on its axis is the same as the time it takes the moon to make a complete revolution around the earth. Forty-one percent of the moon is always visible, eighteen percent sometimes visible, and the other forty-one percent never visible. Rocket trips will provide scientists with an opportunity to find out more about the other side of the moon.

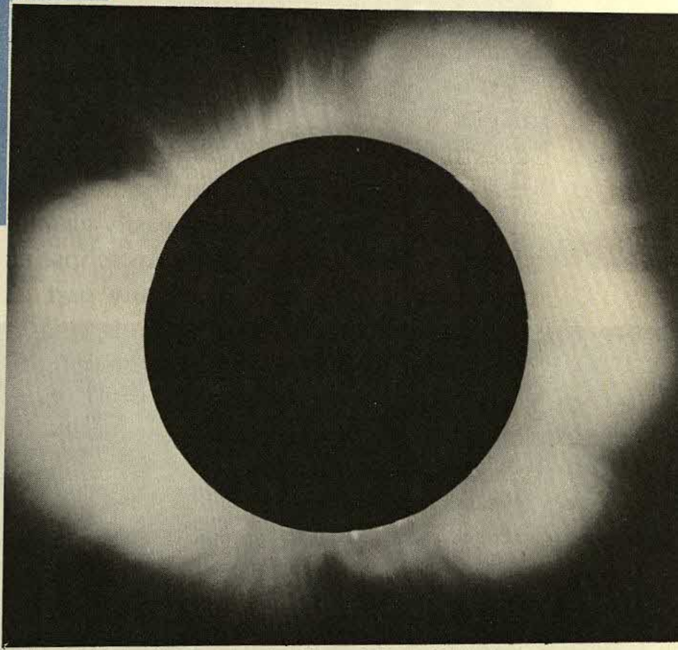
When the first space travelers arrive on the moon, they will find conditions quite different from those on the earth. The lesser surface gravity will make it much easier to move about. On the lighted side, sunlight will be intense. Because there is no atmosphere to screen out the harmful ultraviolet rays, there will have to be some kind of protection from them. There is no twilight between day and night, and there will be no sound. The surface of the moon is a lifeless desert covered with fine dust. In the black sky, an observer will be able to see stars day or night. Can you tell why the sky would appear black?

Solar and Lunar Eclipses

You will recall that the moon moves around the earth once in about twenty-nine days. On most occasions, the moon's orbit takes it slightly above, or below, a direct line to the sun. At least twice each year, and sometimes as often as five times each year, the moon passes directly between the earth and the sun. When this happens, the sun appears to be hidden behind the moon. This is called a ***solar eclipse.*** You may wonder how the sun, whose diameter is 400 times that of the moon, can be hidden by the moon. This



When a solar eclipse occurs, as diagrammed at left, solar corona is visible.



Mount Wilson Observatory

is possible because the sun is about 400 times as far away from the earth as the moon is, and it appears, therefore, to be about the same size as the moon.

You will see from the diagram above, left, that an eclipse of the sun is actually the shadow which the moon casts on the earth when it comes between the sun and the earth. When the entire surface of the sun appears to be covered by the moon, there is said to be a ***total eclipse*** of the sun. At that time, the entire surface of the sun may be invisible to any one observer for as much as seven minutes. A total eclipse can be observed from only a small part of the earth's surface at any one time. From a larger area of the earth's surface, the sun appears to be only partially hidden by the moon. This is a partial solar eclipse. The area from which a partial eclipse could be observed is shown in the lighter shading in this diagram.

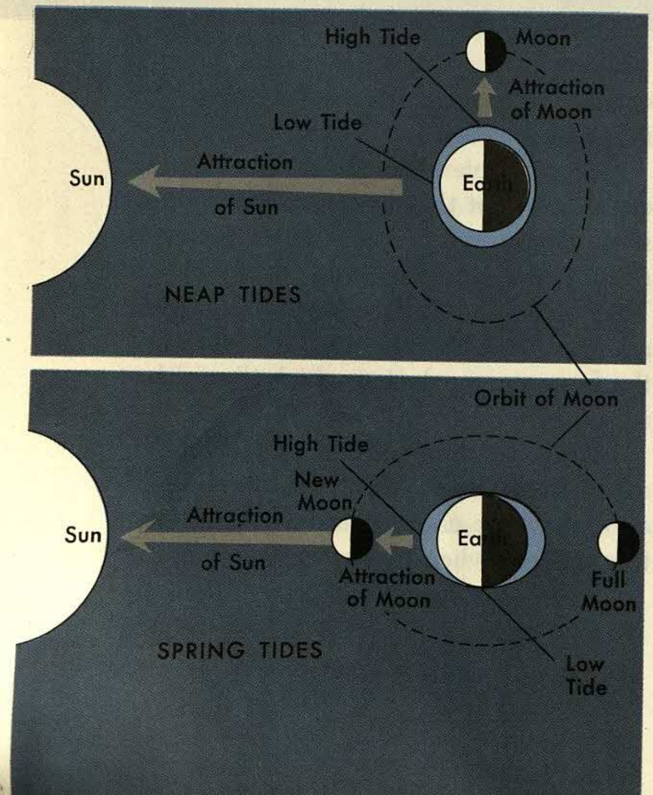
Astronomers, on the basis of long and careful observation, can predict the exact time of a solar eclipse and the exact area of the earth from which it will be visible. Because every solar eclipse is not a total eclipse, there may not be a total eclipse in any one year.

Eclipses have little direct effect on our daily lives, but they are interesting to observe. Even today, astronomers travel to distant places to observe a total eclipse. They make careful preparations long in advance in order to make the best use of the few minutes during which the eclipse is visible.

Before the ***coronagraph*** was invented, astronomers could study the ***corona*** and ***chromosphere*** of the sun only during the total eclipse when the main surface of the sun was hidden by the moon's shadow. The chromosphere is the reddish layer of incandescent gases around the sun, visible at a total eclipse. The corona is a crown, or halo, of luminous light around the sun, which is visible at the same time. The coronagraph is a special-type telescope, which photographs the inner corona.

When the earth is in a direct line between the sun and the moon, the moon goes into the earth's shadow and it may then become invisible. Usually, however, it turns a coppery red and is easily visible. This is called a ***lunar eclipse.*** An eclipse of the moon can be seen from any part of the earth from which the moon is visible. There are never more than three lunar eclipses in a year, and some years there are none.

When the moon is in the position shown in upper diagram, tides are lower than when the moon is in either of the positions in lower diagram.



Earth's Tides

People who live near the ocean, and those who enjoy ocean bathing, know that twice daily the water along the shore rises as the tide comes in and falls as the tide goes out. When the water is rising, the tide is called ***high,*** or ***flood, tide.*** When it is falling, it is called ***low,*** or ***ebb, tide.***

Though it has long been known that there is some connection between the moon and the tides, astronomers have found it difficult to give a complete explanation. It is known, however, that the gravitational pull of the moon and the sun upon the earth tends to pile up the water, as shown in the diagram. Although the moon is much smaller than the sun, its tidal pull upon the earth is twice as great as that of the sun because it is much nearer to the earth. The high tides are highest, and the low tides are lowest, when the moon and the sun are pulling together in a straight-line position with the earth. This happens twice a month—when there is a new moon and a full moon. Although these tides are called ***spring tides,*** the term "spring" has no reference to the season of the year.

Twice each month, during the first quarter and the last quarter of the moon, the sun and the moon are at right angles to the earth. See the diagram at the left. Because they are pulling on the earth at right angles, the high tides are then at their lowest and the low tides at their highest. These tides are called ***neap tides.***

If the moon and the sun always were in the same positions, high and low tides at any particular place would occur at the same time each day. The moon, as you know, appears to revolve around the earth once in about every twenty-nine days. Because the position of the moon changes, the time of high and low tides at a particular port may be from a half hour to an hour-and-a-half later each day. From careful observations made over many years, the time of high and low tides for any ocean port can be calculated and predicted with great accuracy. Tables based on these predictions are very valuable to fishermen and to navigators in launching and docking ships.

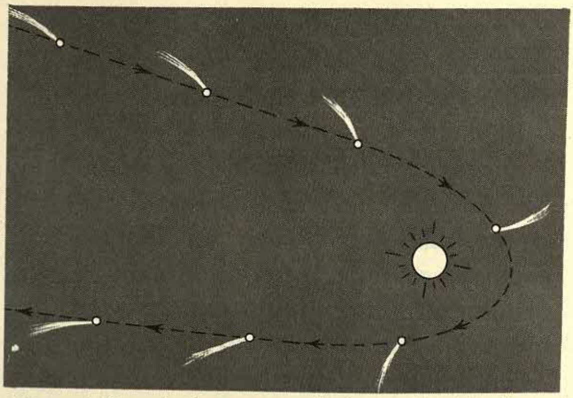
COMETS

People in ancient times feared the comets because of their unusual appearance. Once the nature of comets was understood, fewer people were afraid of them. Although most comets have both a head and tail, some comets are tailless. The central part of the head is probably made up of small solid particles, while the outer portion is made up of extremely thin gases. The tail is a very thin, gaseous material and does not appear until the comet approaches the sun. The tail does not always trail behind the head of the comet, but it always extends away from the sun.

Some comets have a diameter greater than that of the sun, whereas others may be much smaller than the earth.

If the earth should pass through the tail of a comet, as it did in 1910, you would see only a display of "falling stars." If the head of a comet should hit the earth, that might be a more serious matter.

Comets are considered to be members of the solar system because they move around the sun. The orbits of most comets



Comet Cunningham was photographed in December, 1940, as it hurtled through space. Diagram at top shows that comet always directs tail away from sun as it comes toward sun.

Mount Wilson & Palomar Observatories

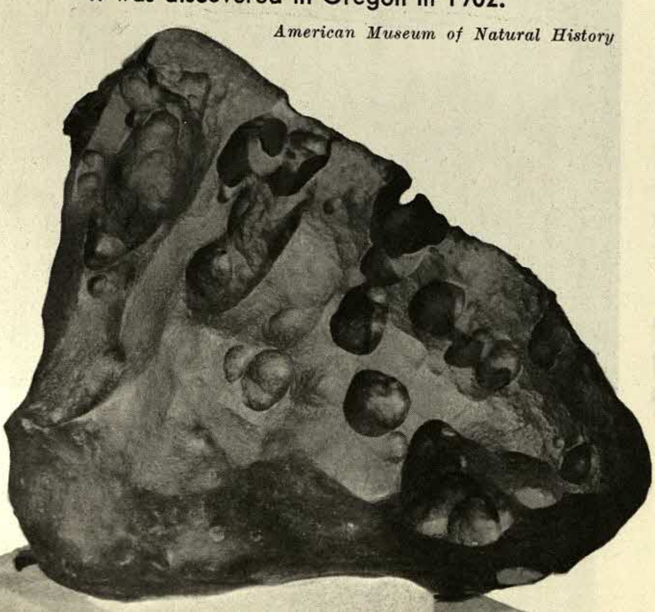
extend beyond the orbit of the planet farthest from the sun. Some are so far from the sun that their periods of revolution have not been determined. Because comets are visible only when they are near the sun, it is believed that not more than ten percent of the existing comets can be seen from the earth. Halley's comet requires about seventy-six years to complete its trip around the sun. Another comet that has been discovered completes its orbit in little more than three years.

METEORS AND METEORITES

Within the solar system there are many chunks of rock and metal that usually move through space in clusters, or swarms, like the material in comets. They seem to come from comets that have broken up, and they travel at very great speeds. When they enter the atmosphere of the earth, they rub against the gases there. This rubbing, or friction, causes them to become very hot. Most of the chunks are completely burned and thus never reach the earth. They are called shooting stars, or ***meteors.*** It is estimated that more than 10,000,000 meteors enter the earth's atmosphere every day.

The meteorite below weighs almost sixteen tons. It was discovered in Oregon in 1902.

American Museum of Natural History



The larger chunks that are not completely burned in the atmosphere fall to the earth. They are called ***meteorites.*** Some of them consist mostly of iron and nickel, while others are stone.

A meteorite weighing many hundreds of tons is believed to have fallen in Arizona several thousand years ago. Some believe that it was the head of a comet. The crater it formed is almost a mile across the rim and about 550 feet deep.

Because many meteorites explode and others fall in places where no one lives, it is very difficult to determine how many meteorites hit the earth each year. Estimates range from 70 to 1,100 a year. The likelihood of being hit by a meteorite is very slight.

SUMMARY

The earth is very much like a station in space. Because of the centrifugal effect of its rotation, it bulges somewhat at the equator and flattens out at the poles. It is, therefore, not a perfect sphere. It has a magnetic field. Its magnetic poles are located some distances from the poles of its axis. The earth is more than five times as dense as water.

Although the earth's rotation has been used as a master clock, it is not so reliable a timekeeper as it was once thought to be.

The gravitational pull of the moon causes the earth to wobble slightly as it rotates. The tilt of the earth's axis accounts for differences in the length of day and night and changes in the seasons as the earth revolves around the sun. Because places east and west of each other on the earth receive the sun's light at different times, it has been necessary to establish time zones and an international date line. There are four standard time zones across midcontinental United States.

Much has been learned about the side of the moon which always faces the earth because the moon is earth's nearest neighbor in space. The moon causes solar eclipses and is one of the causes of tides on the earth. Changes in the moon's appearance at different times are accounted for by the fact that it is viewed from different positions as it and the earth revolve around the sun.

Comets are considered to be members of the solar system because they revolve around the sun. Most of them have orbits that extend beyond the orbits of other members of the solar system. Because of this, the periods of revolution for many of the known comets have not yet been determined. It is believed that meteors and meteorites are chunks of metal and rock from comets that have broken up as they moved through space.

Activities

A. *Testing Yourself*

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. An imaginary line through the earth from one pole to the other is called a polar (a) diameter (b) sphere (c) meridian (d) circle.

2. Astronomers speak of the earth as an oblate spheroid because it (a) is larger than the moon (b) is at the center of the celestial sphere (c) is slightly flattened at the poles (d) has high mountains and deep oceans on its surface.

3. It is believed that the earth's core is made up largely of (a) iron and steel (b) nickel and stone (c) silver and lead (d) nickel and iron.

4. If seen through a telescope on Venus, the earth in the night sky would look like (a) a brilliant star (b) a bright round disk (c) a dim star (d) the moon as viewed from the earth.

5. The slowing down of the earth's rotation means that, in terms of sun time, days are getting (a) longer (b) colder (c) shorter (d) darker.

6. At different times during the year, the earth is at different distances from the sun. This is accounted for by the fact that the earth's orbit is (a) a perfect circle (b) an ellipse (c) is getting smaller (d) is getting larger.

7. Because the earth wobbles slightly as it rotates (a) it will soon stop rotating (b) it is flat at the poles (c) Polaris will not always be the Pole Star (d) the earth's axis is changing.

8. There are twelve hours of daylight and twelve hours of darkness on March 21 because (a) the earth is nearer the sun (b) of precession (c) the sun illuminates

the earth from the North to the South Pole (d) of daylight-saving time.

9. When it is noon in the Eastern standard time zone clocks in all other standard time zones in midcontinental United States will show (a) 11 a.m. (b) p.m. times (c) 10 a.m. (d) a.m. times.

10. Astronomers have observed that when stars disappear behind the moon their light does not become dimmer before they disappear completely. This evidence supports the belief that the moon (a) is round (b) rotates (c) revolves around the sun (d) has no atmosphere.

11. Only one side of the moon is seen from the earth because (a) the moon's period of rotation and revolution is the same (b) only one side is lighted (c) it does not rotate (d) it has no atmosphere.

12. When the moon casts a shadow on the earth (a) there is a solar eclipse (b) it is night on the earth (c) there is a lunar eclipse (d) the earth is between the sun and the moon.

13. When the sun and the moon are pulling together in a straight-line position with the earth, high tides are highest and low tides are lowest. This happens (a) only in the spring (b) on leap year (c) once a month (d) twice a month.

14. Comets are (a) small stars with gaseous tails (b) members of the solar system (c) formed by swarms of meteorites (d) frequently hitting the earth.

15. Meteors and meteorites are believed to be pieces of broken-up (a) planets (b) moons (c) comets (d) stars.

B. Conducting Demonstrations

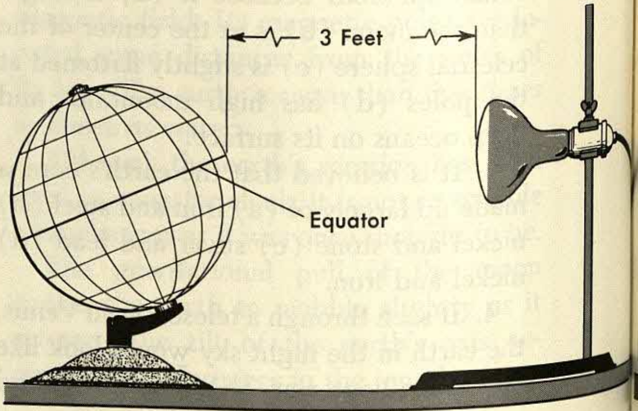
1. Use an orange as a model of the earth to demonstrate the meaning of an oblate spheroid. After you have done this, cut the orange in half. Now demonstrate the meaning of polar diameter and equatorial diameter. How would you cut the orange now to demonstrate the geometrical definition of a sphere?

Think of other kinds of models you could use to demonstrate the same ideas.

2. Find someone who is good at spinning a top with a string. Have him spin the top and watch how it soon begins to wobble. The axis is a straight line through the top, around which it turns. Note how the end of the top's axis points in different directions as the top wobbles. Use this demonstration to explain why Polaris will not always be the North Star.

3. Here is something you can do to demonstrate that (a) the rotation of the earth on its axis as it revolves around the sun accounts for day and night, and (b) changes in the length of day and night are caused by the tilting of the earth's axis.

You will need an earth globe, a clear glass heat lamp, a ringstand and clamp, and an extension cord.



Arrange the heat lamp and globe as shown in the diagram so that the rays from the lamp shine directly on the equator. Darken the room, turn on the lamp, and observe the lighted and darkened areas of the globe. Rotate the globe on its axis. Change the position of the globe so that its axis is tilted the way the earth's would be on March 21, June 22, and September 22. Observe the light and dark areas as the globe is rotated.

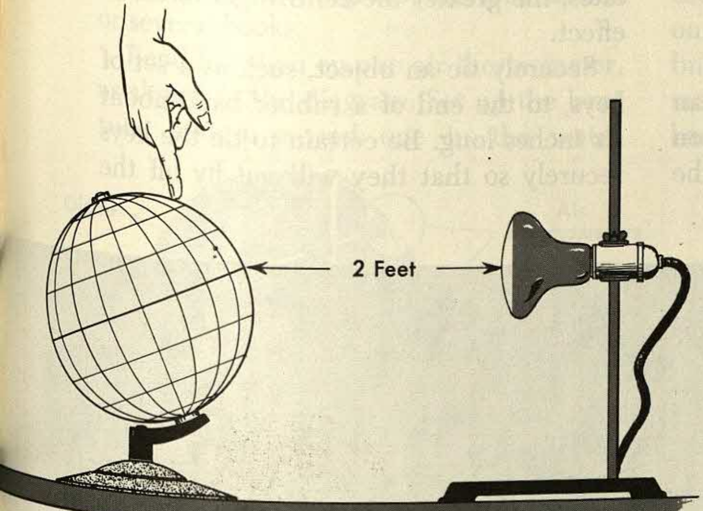
4. The following demonstration will help you to understand better that the tilting of the earth on its axis causes the sun's rays to be more slanted at one time than another and is, thus, one of the causes of the seasons.

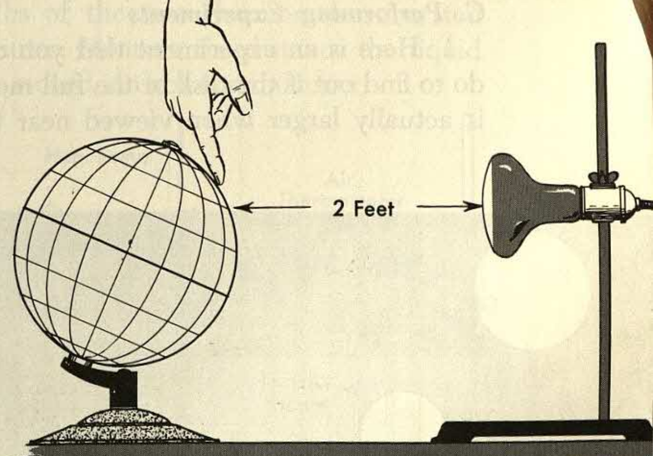
Place the globe about two feet from the lamp and tilt the North Pole away from the lamp. Place your finger upon the part of the globe representing the position of the state in which you live. Note the amount of heat produced by the rays from the lamp. Now tilt the North Pole of the axis toward the lamp and again note the heat produced by the lamp's rays. In which position of the globe are the lamp's rays more slanted as they strike your finger? In which position of the globe do you feel more heat being produced by the rays from the lamp? Which position of the globe represents winter and which summer in the United States?

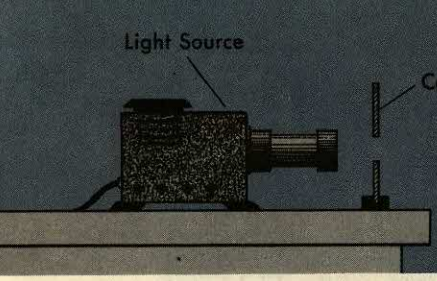
5. Astronomers use photographs to make many different kinds of records. You can record the path of the moon by taking photographs with your camera. The simplest kind of camera can be used.

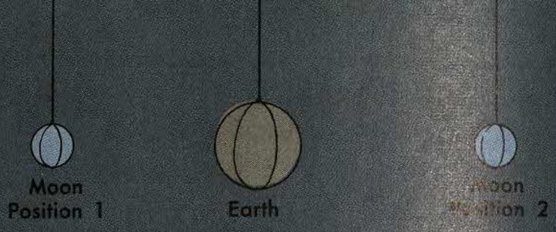
On a night when the moon is clearly visible, set up your camera in the darkest possible place. Look through your finder to focus the camera on the moon. Make sure your camera is away from the light and where it will not be moved. Open the shutter of the camera and leave it open for about two hours. After the film is developed and printed, observe the moon's path across the sky.

Why must you be sure that the camera is not moved while you are taking the picture? Why do you leave the shutter of the camera open for two hours?









6. You can demonstrate an eclipse of the moon. You will need a 250-watt electric light bulb or a lantern-slide projector, an orange, or a rubber ball of the same size, to represent the earth, a ping-pong ball or a golf ball to represent the moon, and a piece of cardboard about six inches square if you use the slide projector.

Arrange the lamp or lantern-slide projector in the position shown in the diagram. If a lantern-slide projector is used, put your six-inch square of cardboard in front of the projector, as shown. Attach strings to the balls representing the earth and moon so that they can be held in position from above. Darken the room and turn on the lamp or the slide projector. Suspend the "earth" and the "moon" in proper positions for a solar eclipse and observe. Rearrange the positions of "earth" and "moon" for a lunar eclipse.

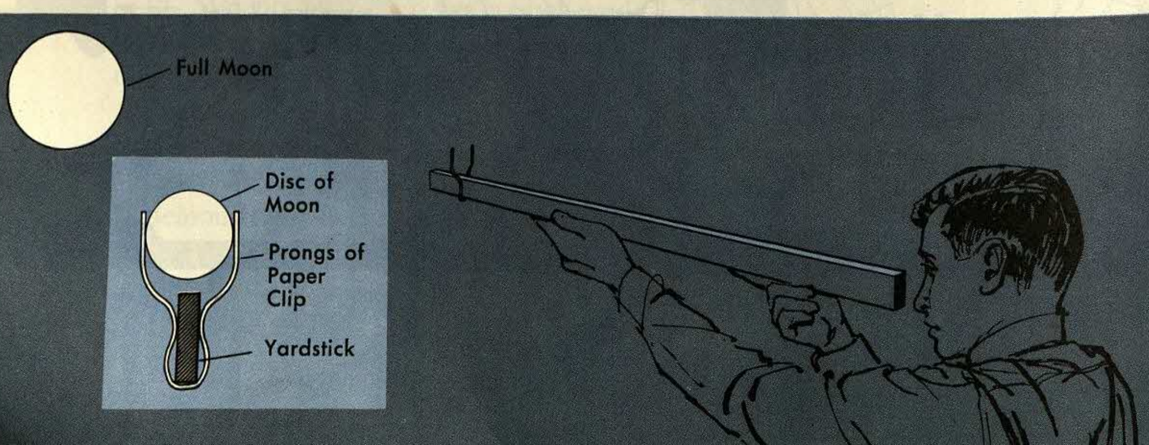
C. Performing Experiments

1. Here is an experiment that you can do to find out if the disk of the full moon is actually larger when viewed near the horizon than when viewed higher in the sky. Before you begin this experiment, what do you think is the answer? Upon what evidence do you base your answer?

Make sighting bars by bending paper clips to fit yardsticks, as shown in the diagram. When the full moon can be seen near the horizon, each observer should sight the moon through the two prongs of the paper clip, as shown in the diagram. The prongs should then be adjusted so that the moon's disk just fits between them. On several occasions during the evening, when the moon is at different altitudes or distances above the horizon, each observer should again use his sighting bar to observe the moon's disk. Make a record of each observation.

2. You can perform an experiment to show that the more rapidly something rotates, the greater the centrifugal force, or effect.

Securely tie an object, such as a set of keys, to the end of a rubber band about six inches long. Be certain to tie the keys securely so that they will not fly off the

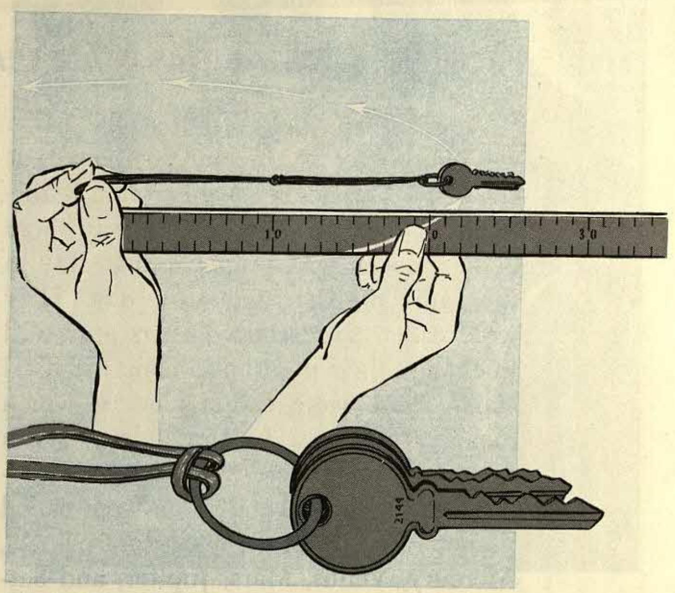


rubber band and hit someone. Twirl the keys as shown in the diagram. At first, twirl them as slowly as you can. Have someone count the number of turns which the keys make in ten seconds. Also have someone estimate the length of stretch on the rubber band. This can be done by using the meter stick as shown. You may use two or three observers and average their estimates. After each observation, increase the number of turns per ten-second period and also have the stretch on the rubber band estimated. Record the observations in a table or a graph. What can you conclude from the evidence? Can you think of other ways of doing this experiment so that your data would be more accurate?

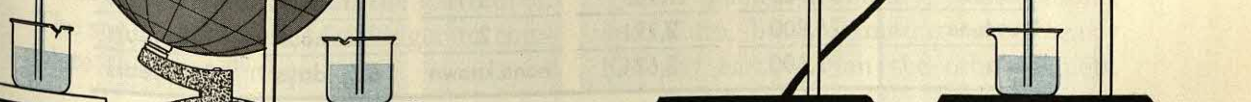
3. Here is an experiment that you can do to test the idea that rays from the sun, when slanted, do not have so great a heating effect as those that strike the earth directly.

You will need three air thermometer tubes, three beakers, red ink, a clear glass "heat" lamp, ringstand and clamps, extension cord, earth globe, and a small box or several books.

Bend the stem on one air thermometer, as shown in the diagram. Set up the bent tube and a second one in the water that is colored by ink, as shown in the diagram. Set up a third air thermometer in the same way, but place it where rays from the lamp cannot reach it. This third tube is your control. Arrange the air thermometers so that the level of the liquid is the same in each. Mark these levels. Turn on the lamp and allow it to shine on the bulbs of the two thermometers for ten minutes. Measure the distance the liquid has moved in each thermometer.



With the set-up above, you can show that the greater the speed of a revolving object, the greater its centrifugal force.



PROBLEM 3: WHAT HAS MAN LEARNED ABOUT THE OTHER PLANETS?

When it was believed that the earth was the center of the universe and that all celestial bodies revolved around it, differences were observed in the way these bodies moved. Many appeared to stay in the same position day after day. They were called ***fixed stars.*** Others appeared to change their positions among the fixed stars. These were called planets, which means wanderers. In those days, seven such wanderers were observed and identified. The sun and the moon were called planets, along with the five bright planets, Mercury, Venus, Mars, Jupiter, and Saturn. Of course, under this system, the earth was not a planet. After the acceptance of the idea that the sun was the center of the solar system, the sun and moon were no longer considered planets, but the earth was.

You probably learned, earlier in your study of science, that there are nine planets in the solar system. The information included in the table on this page will help you review some important facts about the nine planets.

SIMILARITIES AND DIFFERENCES

In trying to describe things such as planets, it helps to look for ways in which they are alike and ways in which they are different. This is what scientists do when they classify things into groups. Biologists, for instance, classify living things into groups and chemists classify materials in the same way. Grouping things in this way makes it easier for you to understand how the many things in your environment are related—how they are alike and how they are different.

As you examine the table of planets, the headings in each column will give you clues to both similarities and differences.

Comparison of Planets of the Solar System

Planet	Average Diameter in Miles	Average Distance From Sun in Millions of Miles	Number of Satellites	Rotation-Length of Day in Earth Time	Revolution-Length of Year in Earth Time
Mercury	3,010	36	0	88 days	88 days
Venus	7,610	67	0	uncertain	225 days
Earth	7,918	93	1	24 hours	365¼ days
Mars	4,140	142	2	24½ hours	687 days
Jupiter	86,900	483	12	10 hours	12 years
Saturn	71,500	886	9	10¼ hours	29½ years
Uranus	29,500	1,783	5	11 hours	84 years
Neptune	26,800	2,791	2	16 hours	165 years
Pluto	3,600	3,671	none known	6¼ days	248 years

Planetary Movements

All planets revolve around the sun. Their orbits around the sun are ellipses. They all revolve around the sun in the same direction—from west to east. Their orbits are located at different distances from the sun. Pluto is 100 times farther from the sun than Mercury.

All planets also rotate. With the exception of Uranus, which "rolls" along in its orbit, they rotate in the same direction in which they revolve—from west to east.

Six of the nine planets are known to have satellites, but the planets do not have the same number of satellites.

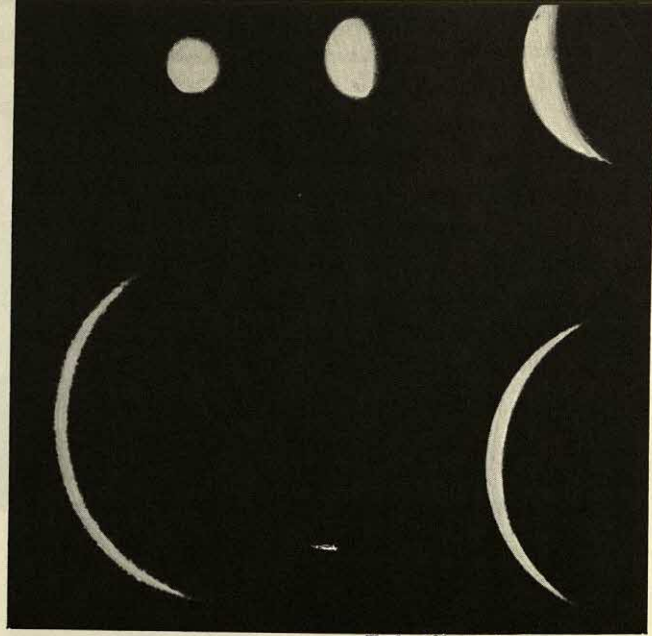
The orbits of most of the satellites are nearly circular. Most of them revolve around their parent planet in the same direction that these planets revolve around the sun. But both their periods of rotation and their periods of revolution differ.

All of the planets and their satellites are seen by sunlight, which reflects from them as they rotate. None of the planets gives off light of its own.

Distances From the Sun

As you will note from the table on page 308 and the diagram on page 264, the orbits of two planets, Mercury and Venus, are inside the orbit of the earth. Because of this position, they are sometimes classified as ***inferior*** planets. The other planets, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto, have orbits farther from the sun than from the earth. They are classified as ***superior*** planets.

The inferior planets complete their revolutions in less time than the earth does. The superior planets take longer to complete their revolutions.



Yerkes Observatory

Phases of Venus are shown above. Planet appears larger during crescent phase because then it is about 120,000,000 miles nearer earth.

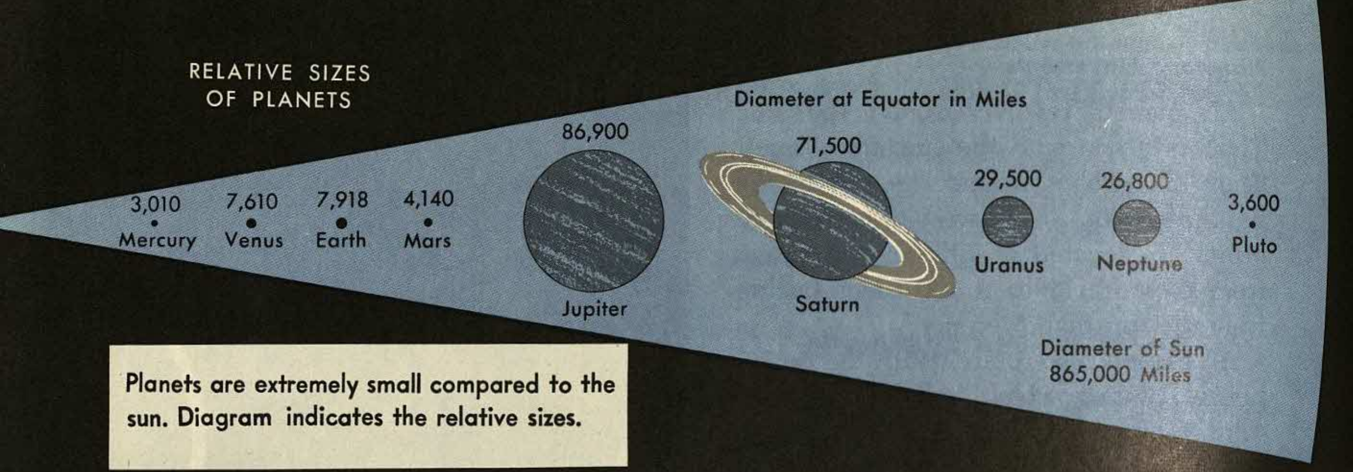
Although planets appear to be starlike to the unaided eye, when they are observed through a telescope, most of them appear as disks, like the moon.

Because their orbits lie between the earth and the sun, the inferior planets go through all phases like those of the moon. The phases of Venus, as seen through a telescope, are shown in the pictures on this page. The superior planets appear only as full phase, or gibbous phase, but never as crescents.

Size of Planets

A further examination of the table on page 308 will reveal the differences in size, ranging from Mercury, the smallest, to Jupiter, the largest.

Four planets, Mercury, Venus, Mars, and Pluto, have diameters more nearly like the earth's than the other planets.



Planets are extremely small compared to the sun. Diagram indicates the relative sizes.

These four planets are sometimes classified as ***terrestrial*** planets. Terrestrial means "like the earth." The other four planets, Jupiter, Saturn, Uranus, and Neptune, have diameters much larger than the earth's. They are called major planets. They are also referred to as the ***Jovian*** planets, which means "like Jupiter."

Density and Composition

The terrestrial planets not only resemble the earth in size, but in other ways as well. As you will recall from Problem 2, page 286, the density of the earth is 5.52 times the density of water, the density of water being taken as 1. The densities of the other terrestrial planets are as follows: Mercury, 5.46; Venus, 5.06; and Mars, 4.12. Little is known of Pluto's density.

It is believed the chemical composition of terrestrial planets is quite similar.

The Jovian planets resemble one another in a number of ways. Although they have huge volumes compared with the terrestrial planets, they are much less dense. Their densities, compared with water as 1, are: Jupiter, 1.35; Saturn, 0.71; Uranus, 1.56; and Neptune, 2.47

Because of the differences in density, the chemical composition of the Jovian planets must be quite different from the composition of terrestrial planets. It is believed that Jupiter and Saturn are composed largely of solid hydrogen. Both planets are believed to have rocky cores. Jupiter's is the larger.

INDIVIDUAL CHARACTERISTICS

Many of the interesting things known about the individual planets cannot be reported when describing the various groups and subgroups. For that reason, a brief summary of additional facts about them follows. Because the earth has been more completely described earlier in this unit, it will not be included here.

Mercury

Mercury is not only the smallest planet, but it is the one nearest the sun. Because its period of rotation and revolution is the same, eighty-eight days, the same side of Mercury is always facing the sun.

The temperature of the sunny side of Mercury is generally about seven times greater than that of the warmest days on earth. Its opposite side receives no direct sunlight and is, therefore, very cold.

Mercury's mass is not much greater than that of the moon. If it ever had any atmosphere, its gravity has not been enough to hold it.

Because of the temperature extremes and lack of oxygen, it would not be possible for any known living thing to exist on Mercury.

Venus

Although Venus is the planet that comes closest to earth, not very much is known about it because of the dense cloud that surrounds it. Astronomers have not been able to find an opening in this cloud through which they can see the surface of earth's next-door neighbor. Consequently, the period of Venus' rotation has not been measured accurately. It is believed to be about thirty days.

The heavy cloud around Venus serves as an excellent reflector of light from the sun. Hence it is the brightest of all planets. When it is at its brightest, it is six times brighter than Jupiter and thirteen times brighter than Sirius, the brightest star that you can see from the earth.

Although it has been established that there is carbon dioxide and water vapor in the dense atmosphere of Venus, it is believed that there is not enough oxygen on Venus to support life as it is known on the earth today.

Mars

Next to Venus, Mars is our closest planetary neighbor. Mars's atmosphere is so thin that an earth man could not live there outside a pressurized suit. It is believed

Lick Observatory

Mars above, is one of our closest neighbors. Between Mars and Jupiter are the asteroids. One of them can be seen below traveling across a star-filled night sky.

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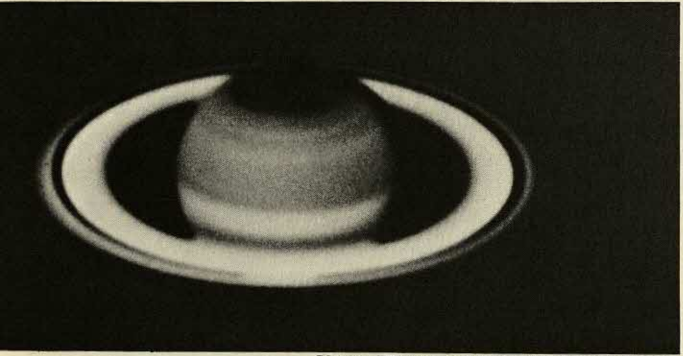
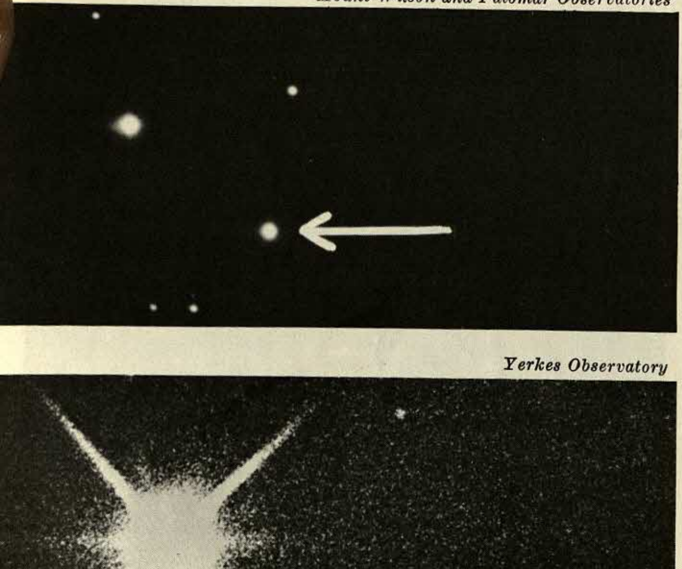


Mount Wilson and Palomar Observatories

Uranus, with four of its moons, or satellites, is shown at top. Below it is Saturn, surrounded by its rings, thought to be made up of small, solid particles. Distant Pluto, indicated by arrow, is next. At the bottom is Neptune, which was photographed with two of its known satellites.

Mount Wilson and Palomar Observatories



Yerkes Observatory

that there is a small amount of oxygen in Mars's atmosphere and some water on it.

Its axis tilts much as does that of the earth, and it has seasons like those on the earth. During the daytime the temperature on its surface rises to about 80°F. At night, however, the temperature drops quickly to −95°F.

Through telescopes, astronomers have seen large reddish deserts, blue cloud formations, and white polar caps on Mars. During the spring, the polar caps appear to melt, and, in part, to be replaced by blue-green areas. Later in the season, these areas turn brown.

Some astronomers claim to have seen delicate lines forming a regular pattern over the surface of Mars. Others, with telescopes just as good, have been unable to see them.

There has been a good deal of speculation about the possibility of life on Mars. If there is life, it would have to be pretty rugged to survive.

Jupiter

Jupiter is so large that if it were hollow, all the other planets could be put inside of it with room to spare. It is so far from the sun that the sunlight which reaches it is only about one-thirteenth as strong as that which reaches the earth. With a special instrument, astronomers found the surface temperature of Jupiter to be about −200°F.

The atmosphere surrounding Jupiter is so thick that the planet's surface cannot be seen from the earth.

Jupiter has twelve satellites, or moons, as they are called. It also has a family of more than two dozen comets.

Asteroids

Between Mars and Jupiter, there is a large group of little planets ranging in size from 480 miles in diameter to mere chunks of rock. They are called ***asteroids,*** or ***planetoids.*** More than 1,500 of them have been discovered. One of these asteroids, Eros, has come within 14,000,000 miles of the earth. It is thought that the asteroids are pieces of larger planets which were broken up in an unknown way long ago.

Saturn

Through the telescope, Saturn presents one of the most spectacular sights in the heavens. It is surrounded by a beautiful system of rings which are really a multitude of fine particles revolving around it. Half the light received from Saturn is reflected to earth from these rings.

Saturn, like Jupiter, has a dense atmosphere. Because of its distance from the sun, sunlight there is only about 1/100 as strong as it is on the earth, and the temperature is very low.

Uranus and Neptune

Three planets beyond Saturn's orbit have been discovered since 1780. Uranus was found by Sir William Herschel in 1781. Because it looked like a disk through the telescope, it was identified as a planet. Planets usually appear as disks through a telescope, whereas stars are always points of light.

A second planet, Neptune, was discovered in 1846. Before it was actually discovered with a telescope, both its presence and position had been predicted because of the effect of its gravitational pull on Uranus.

Neptune and Uranus are alike in several ways. As was noted on page 308, they are about the same size. Both surfaces are covered with heavy clouds.

Uranus receives only 1/400 as much sunlight as the earth, and Neptune only 1/900 as much sunlight.

Pluto

The existence of Pluto, the third planet beyond Saturn, had also been predicted mathematically before it was discovered in 1930 during a thorough photographic search. As yet, very little is known about Pluto, about the size of the earth.

Pluto's extreme distance from the sun would make it a very cold body. Its surface temperature is about −359°F.

It is doubtful that any sort of life exists on Uranus, Neptune, or Pluto.

SUMMARY

One method by which things can be understood better is by comparing them one with another. In comparing things, you look for both similarities and differences. Planets have been compared in this way and classified into two main groups. The terrestrial planets are those most like the earth. These are Mercury, Venus, Mars, and Pluto. The Jovian planets are those most like the giant planet Jupiter. Saturn, Uranus, and Neptune are Jovian planets. These planets are also called the major planets.

It is extremely doubtful that life, such as is known on the earth, could exist on any other planet. If it does, however, it will most likely be found on one of the terrestrial planets.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The planet which does not rotate from west to east as it revolves around the sun is (a) the earth (b) Venus (c) Uranus (d) Jupiter.

2. Planets whose orbits are inside the earth's orbit are classified as (a) satellite planets (b) inferior planets (c) terrestrial planets (d) superior planets.

3. Although planets appear to be starlike to the unaided eye, when observed through a telescope most of them appear as (a) disks (b) crescent moons (c) moons without atmosphere (d) meteors.

4. Mercury, Venus, Mars, and Pluto are classified as terrestrial planets. One of the ways in which they are similar is their (a) distances from the sun (b) periods of revolution (c) atmospheres (d) densities.

5. It is believed that Jupiter and Saturn are composed largely of (a) solid hydrogen (b) iron and nickel (c) uranium (d) solid carbon dioxide.

6. Because Mercury's period of rotation and revolution is the same it (a) moves more slowly than the other planets (b) always has the same side facing the sun (c) is classified as a Jovian planet (d) has no temperature variations.

7. Because Mars's axis tilts in the same way as that of the earth, it has (a) phases (b) night and day (c) an atmosphere (d) seasons.

8. The period of Venus' rotation has not been measured accurately because it (a) rotates too rapidly (b) is too far from the earth (c) has a dense atmosphere (d) is seen only as a crescent.

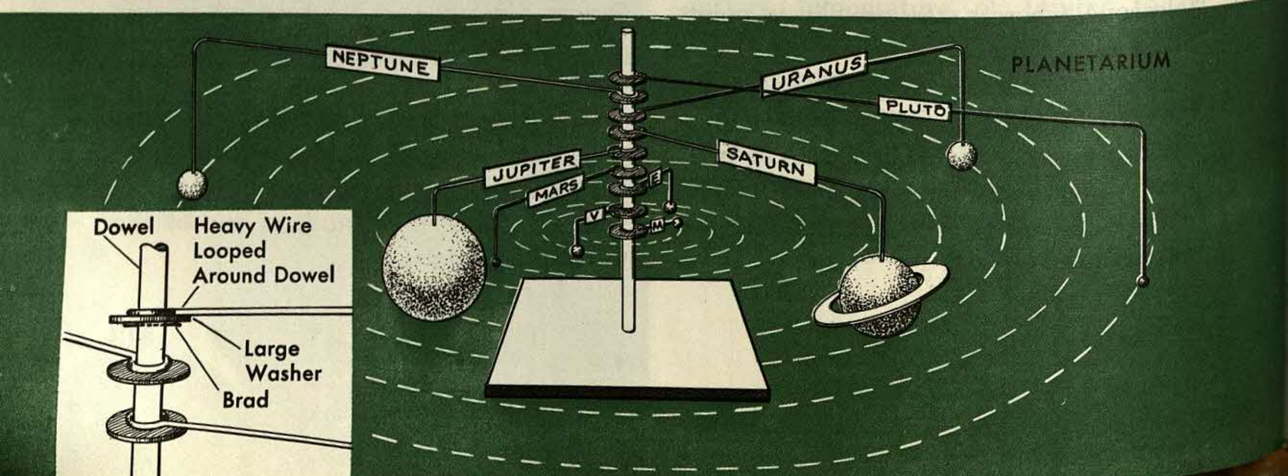
9. The planet that has rings around it is (a) Saturn (b) Venus (c) Uranus (d) Mercury.

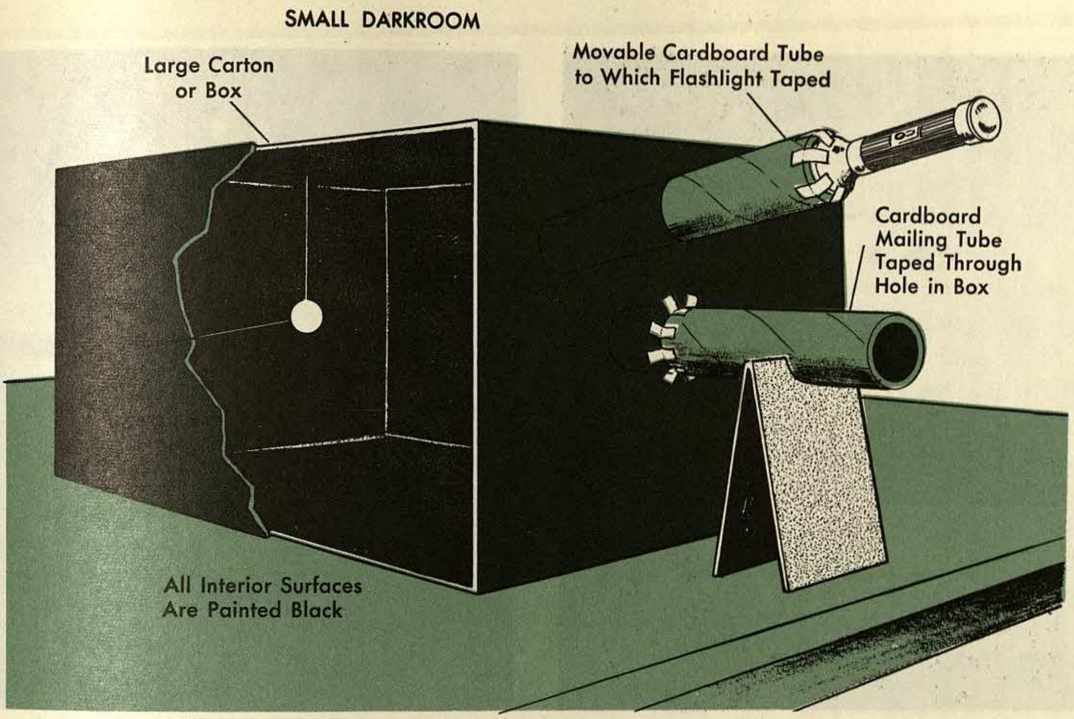
10. The planet with the lowest temperature is (a) Mercury (b) Saturn (c) Uranus (d) Pluto.

B. Building Models

1. You can obtain light plastic balls of different sizes from the Science Materials Center, 59 Fourth Avenue, New York City 3. These balls can be used to build a model solar system, called a ***planetarium.*** They can be mounted on wooden dowels, or suspended from strings.

2. Models of planets can also be built from rubber balloons. Blow up each balloon to the size needed and then cover it with plaster of Paris.




SMALL DARKROOM
Large Carton or Box
Movable Cardboard Tube to Which Flashlight Taped
Cardboard Mailing Tube Taped Through Hole in Box
All Interior Surfaces Are Painted Black

C. Working Out Classification Systems

1. Work out a system for classifying all of the nonliving objects in your classroom.

2. Devise a system for assigning to various scientific fields the knowledge used by astronomers in making their discoveries. Why do astronomers employ the principles of more than one scientific field in arriving at their conclusions?

D. Planning Demonstrations and Experiments

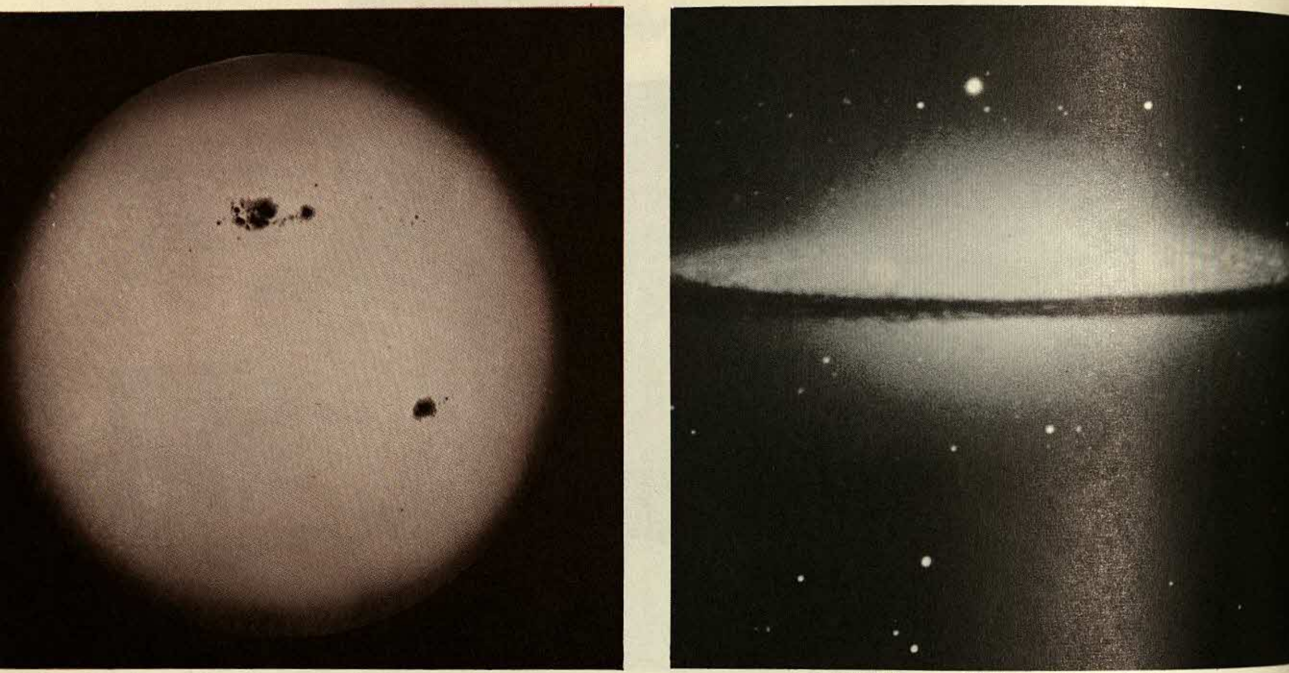
1. Plan ways of demonstrating the fact that you see most things, including planets, by reflected light. You will need a room from which you can exclude all the light. If such a room is not available, you can make a small darkroom out of a box.

2. Plan experiments to test the idea that the farther an object (such as a planet) is located from a radiating body (such as the sun), the lower the temperature of the object will be.

3. Plan ways of demonstrating how a spherical object, such as a rubber ball, can rotate at the same time that it revolves around another object. Use this to explain the periods of rotation and revolution of planets.

4. Plan a way of demonstrating how Mercury's period of rotation and revolution could be the same.

5. Find out how to measure the density of different objects such as pieces of coal and rocks of different kinds. Find objects with densities similar to those of terrestrial planets. Find other objects with densities similar to those of Jovian planets.



Mount Wilson and Palomar Observatories

Largest of sunspots ever photographed is shown above, left. At right is spiral nebula in Virgo.

PROBLEM 4: WHAT HAS BEEN LEARNED ABOUT THE SUN AND OTHER STARS?

On a night when you were watching the stars, did you ever wish that you could see one close up? The stars which you see in the night sky are very far from the earth. The nearest one, ***Alpha Centauri,*** is four-and-a-half light years from the earth. Since a light year is 5,880,000,000,000 (5.88×10^{12}) miles, this star is 26,000,000,000,000 (2.6×10^{13}) miles from the earth. There is another star, however, which is only 93,000,000 (9.3×10^{7}) miles from the earth. This star is the sun, which you see daily at close range when the day is clear. Even through telescopes, no other stars will appear much larger than points of light. Much of what is known about other stars has been learned by studying the sun, our closest star.

THE SUN

Of course, you should never look directly at the sun on a clear day. Although it is 93,000,000 miles away, it is so bright that it would damage your eyes. You can look at the sun safely through a darkened photographic film, or through a pinhole in a card. When you look at the sun through a pinhole, it looks like a bright white disk much smaller than a dime held at arm's length. In angular measurement, it is only half a degree in diameter. If the angular measurement across the sky from the horizon in the east to the horizon in the west is 180°, how many suns would it take to reach across the sky?

Size of the Sun

How can an object which appears to be so small give the earth so much heat and light? The sun is actually a huge globe. Its diameter is about 865,000 miles. It would take more than 100 earths, side by side, to reach across the sun at its equator. If the sun were a hollow ball, you could pack more than 1,300,000 earths inside it. Although it is huge, the sun's average density is only one quarter that of the earth. Can you explain this?

Composition of the Sun

The sun is actually a huge globe of very hot gases. In the interior, the gases are under high pressure. The surface temperature of the gases is about 6,000°K, while interior temperature is 20,000,000°K (2.0×10^7).

Some sixty chemical elements, including iron, have been identified in the sun.

Atmosphere of the Sun

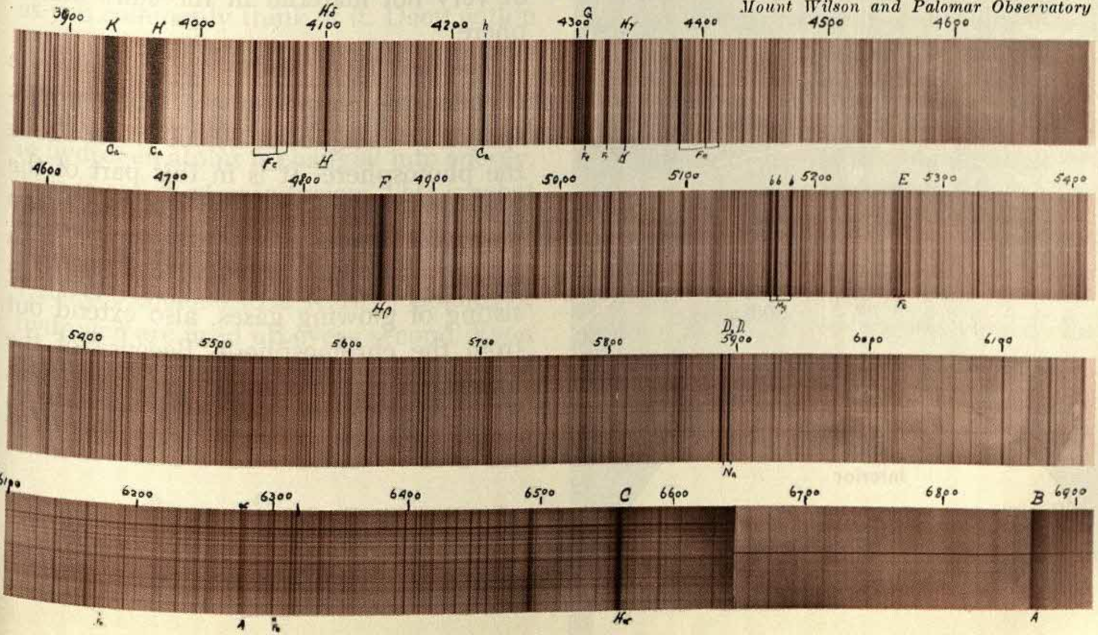
The sun is surrounded by the cooler layers of its atmosphere. As shown in the diagram on page 318, the sun's atmosphere has been divided into a number of layers. The layer which you ordinarily see is called the ***photosphere.***

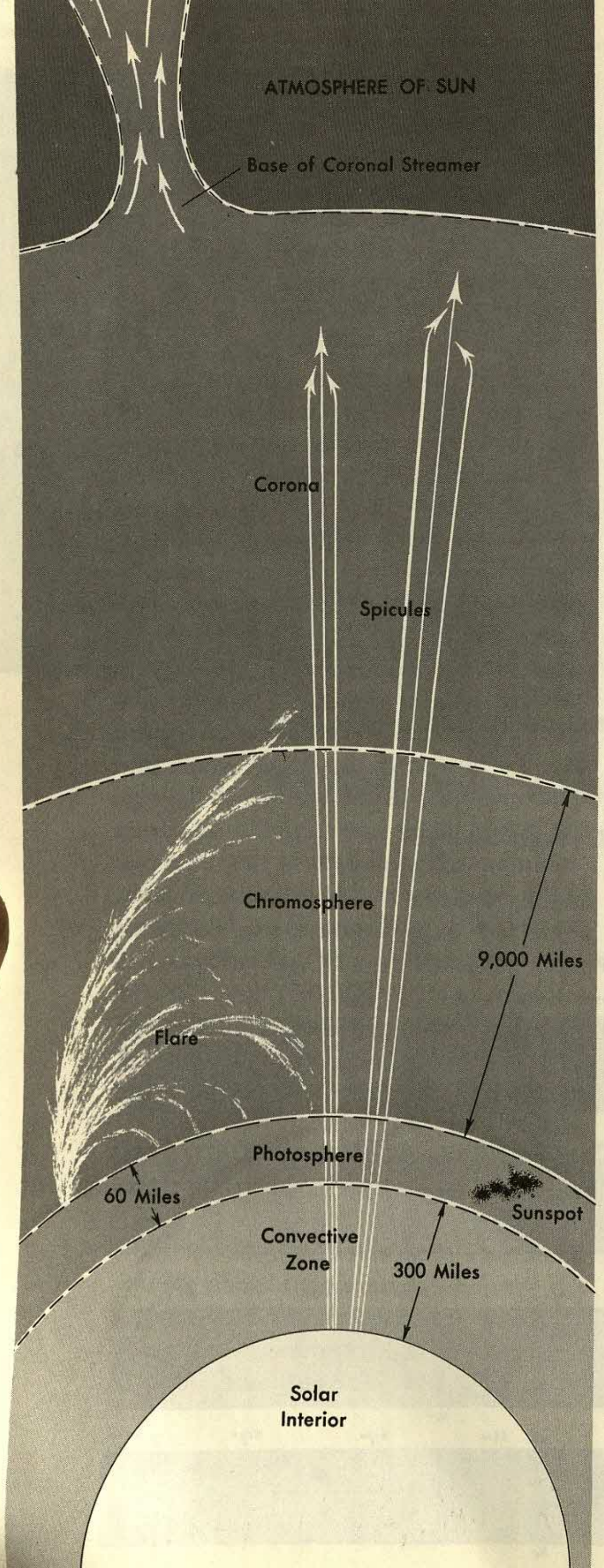
Dark areas, called ***sunspots,*** appear from time to time on the surface of the sun. A spot is usually seen first as a small round pore about 1,200 miles in diameter. The pores grow rapidly into small spots and usually disappear within a day. However, a few of them develop into spots more than 20,000 miles wide. Sunspots appear black because their temperature is about 1,500°K cooler than the photosphere of the sun.

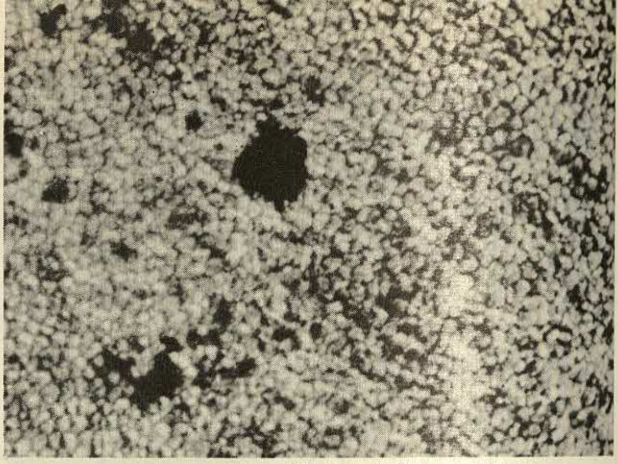
In some places on the sun, there is an outward flow of material from the sunspots. At other places, there is an inward flow. By observing the rate at which sunspots move across the surface of the sun, the period of the sun's rotation has been determined. Not all parts of the sun rotate in the same periods. At the solar equator, the period is 24.9 days. At a latitude of

Spectrum, made with a thirteen-foot spectroheliograph, shows prominences on sun's surface.

Mount Wilson and Palomar Observatory







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Granules in the sun's photosphere are above.

35°, the period is 26.8 days. Other ways than the movement of sunspots have also been used to measure the period of solar rotation.

When certain kinds of cameras and films are used with telescopes to photograph the sun, the photosphere appears to be covered with bright specks called ***granules.*** They look something like grains of white rice. Although the granules appear to be small when photographed, they actually are hundreds of miles wide. They are believed to be the tops of vertical updrafts of very hot material in the sun's atmosphere.

The next layer of the sun's atmosphere is called the chromosphere. The chromosphere extends about 30,000 miles above the photosphere. It is in this part of the sun's atmosphere that the solar ***flares*** are produced. These are photographed with special equipment. Red ***prominences,*** consisting of glowing gases, also extend out from the chromosphere. Because of the brightness of the photosphere, the prominences can be photographed only during a total eclipse of the sun, or with a special kind of telescope called a coronagraph. The prominences range in size from very small eruptions to enormous outbursts extending a million miles above the chromosphere. It is probable that some prominences are invisible when they leave the surface of the sun. They may become visible at high altitudes above the sun and stream back into it.

The corona is the outermost layer of the sun's atmosphere. It is made up of very thin gases and ordinarily can be seen only during a total solar eclipse. Its weak light is only half as bright as the full moon. The inner corona is yellowish, but the outer corona is white. All in all, it has a pearl gray appearance. Streamers from the corona extend millions of miles into space. During IGY, evidence was obtained which indicates that these thin streamers may extend as far as the earth.

Energy of the Sun

From where does the sun obtain its great energy? The more deeply the gases are located in the sun, the hotter they are. These gases are not produced by burning, as you commonly think of it. Deep within the sun, where temperatures are extremely high, hydrogen is changed into helium. When this happens, some of the matter in hydrogen atoms is changed into energy. This is called ***atomic fusion.*** This is what happens when a hydrogen bomb is exploded. In the atomic furnace of the sun, 1,200,000,000,000 (1.2×10^{12}) pounds of hydrogen are used up every second. Even at this rate, it will take many billions of years before the sun consumes all of the hydrogen in it.

Sun's Effects on the Earth

Aside from tidal energy and radioactive materials in the crust of the earth, the sun is the source of all energy on the earth. It is the energy locked in foods and fossil fuels. It is the energy of winds, storms, and water that runs large hydroelectric plants.

There is some evidence to support the belief that sunspot activity, which reaches its maximum every eleven years, has an effect on weather and on conditions that affect the growth of plants on the earth. Evidence is quite clear that the flares and prominences of the chromosphere cause radio fade-outs, northern-light displays, and cosmic radiation, and result in changes in the magnetic fields of the earth. These effects become more pronounced during periods of maximum sunspot activity.

Some of the most spectacular effects of the sun upon the earth are the ***aurora borealis*** and the ***aurora australis.*** These are commonly called the northern lights and the southern lights. It is believed that the auroras are caused by streams of charged particles originating in the sun and colliding with air molecules, thus causing them to glow. These glowing particles follow the earth's magnetic lines of force and are, therefore, concentrated in the regions of the earth's magnetic poles.

THE MILKY WAY

If you live where lights from the earth will not interfere with a good view of the stars in the night sky, you should, on a moonless night, be able to see the ***Milky Way.*** Right after dark, in the late summer,

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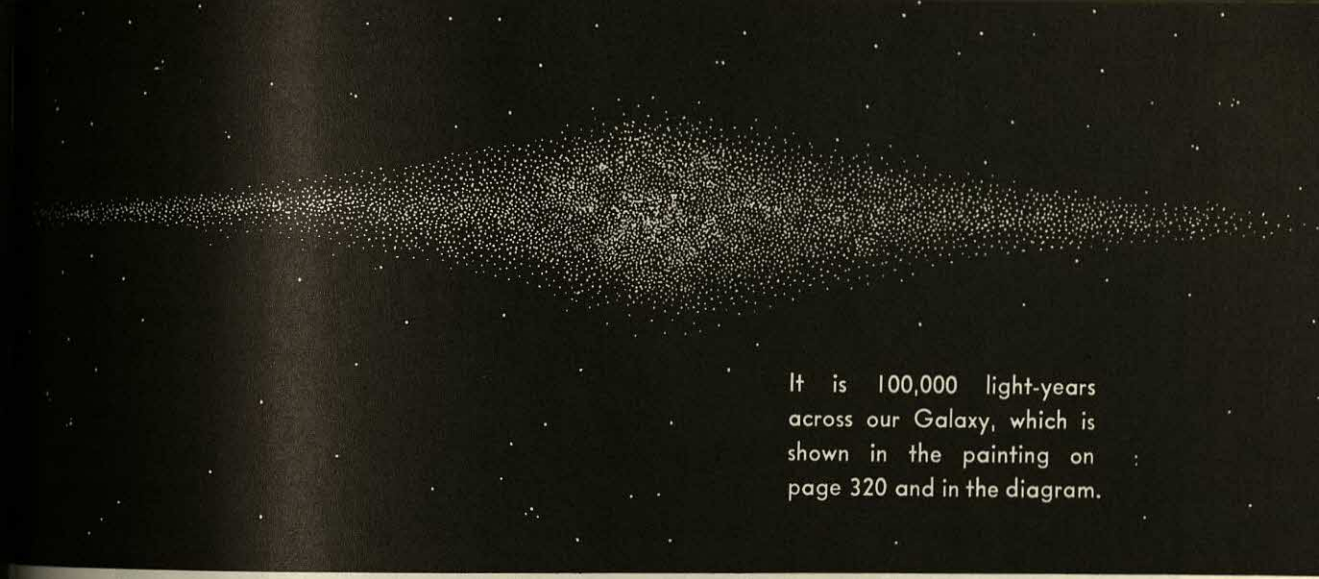
the Milky Way arches overhead from the northeast to the southeast horizon. It is a luminous band formed by the combined light of billions of stars making up the system of stars in which you live. Just as the sun and its planets, including the earth, make up the solar system, so the sun and its many billions of neighboring stars make up a system of stars called earth's ***Galaxy.*** Earth's view of the system of stars in this band is called the Milky Way.

Size of Galaxy

As you can see from the diagram, earth's Galaxy is shaped something like a wheel with a bump near the axle. The distance from one end to the other is 100,000 (1.0×10^5) light years. It is about 20,000 light years through its thickened portion. The sun is located near the rim, or two-thirds the distance out from the center. When you see the Milky Way in the evening sky, you are looking through that part of the



It is 100,000 light-years across our Galaxy, which is shown in the painting on page 320 and in the diagram.

system where most of the stars are located. Their faint points of light come so close together that they appear like a luminous band in the sky because there are so many of them and they are so far from the earth.

Movement of Galaxy

All the stars are rotating around a central axis in the Galaxy, which is about 100,000 light years in diameter. The solar system is located about 30,000 (3.0×10^4) light years from the center. It takes nearly 225,000,000 (2.25×10^8) years for the solar system to make one trip around the central axis of earth's Galaxy.

Other Galaxies

Even though it may be difficult for you to imagine the tremendous size of earth's Galaxy, you must stretch your imagination even more to get some idea of the vastness of the universe.

Beyond earth's Galaxy are billions of galaxies scattered throughout the universe. They have been observed so far as it is possible to explore with the largest telescopes. The picture of one, the Andromeda Galaxy, as photographed through a telescope, is shown on page 322. This galaxy is 800,000 light years away. The most distant ones that can be photographed with the most powerful telescope are about two billion light years away.

OTHER STARS

Have you ever tried to count the stars? You probably soon gave up, for the sky seems filled with stars far too numerous to count. But without field glasses or a telescope, actually only about 3,000 stars can be seen at one time.

Star Names

Many stars have been named by groups, or ***constellations.*** It was imagined by ancient people that different groups of stars resembled in outline some familiar object. Constellations were, therefore, named

Yerkes Observatory

The Andromeda Galaxy is 800,000 light years away. Its diameter is 150,000 light years.

after that object. Eighty-eight such constellations have been named.

Astronomers name individual stars according to the constellation in which they are located and according to their brightness in that constellation. For example, the brightest star in the constellation Lyra is commonly called Vega, but astronomers also call this star ***Alpha Lyrae.*** Alpha, the first letter of the Greek alphabet, is used for the brightest star. Alpha Lyrae, therefore, means that Vega is the brightest star in the constellation Lyra.

The other letters of the Greek alphabet are used in order in the names of the other stars in the constellation to indicate the order of their brightness. But not all stars can be named in this way because there are only twenty-four letters in the Greek alphabet. Fainter stars are indicated by their position in the constellation.

Sizes of Stars

Regardless of the power of the telescope used, no star, other than the sun, appears to be more than a point of light in the sky. It is extremely difficult, therefore, to measure the size of any star accurately. But astronomers have developed an instrument called an ***interferometer,*** which can be used to measure the diameter of stars. It is attached to a large telescope such as the one on Mount Wilson.

Antares, Alpha Herculis, Omicron Ceti and ***Betelgeuse*** have the largest known diameters. Antares' diameter of 390,000,000 miles, is more than four times the distance from the earth to the sun and more than twice the diameter of the earth's orbit (186,000,000 miles). Antares occupies 90,000,000 times as much space as the sun, but it weighs only about thirty times as much as the sun.

One of the smallest stars known, ***Van Maanen's*** star, is about the size of the earth. If the sun were hollow, more than a million such tiny stars could be packed into it with space to spare. Though Van Maanen's star is about one-millionth as large as the sun, it is about one-fifth as heavy as the sun. The substance making up this tiny star is 66,000 times as heavy as the materials making up the earth. A piece of this heavy star substance about the size of this book would weigh almost 600 tons.

Colors of Stars

The color of a star is a clue to its surface temperature. Bluish-white stars are the hottest. Their surface temperature is approximately 20,000°K. White stars have a temperature of approximately 10,000°K; yellowish white, 7,000°K; yellow, 6,000°K; and orange, 4,000°K. Red stars are the coolest, with a surface temperature of approximately 3,000°K.

Types of Stars

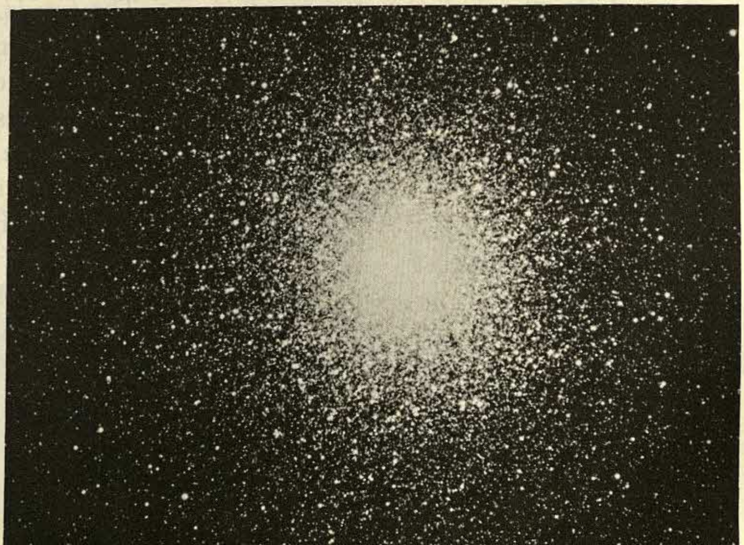
Stars, like many other things in the universe, are not all alike. They have different magnitudes and vary in size and color. Stars are different in other ways, too.

Some stars which appear in pairs are called double stars, or ***binaries*** (BY-nuh-reez). They are called doubles because they are much nearer to each other than to other stars. Some of them appear to revolve around a common center of gravity. One-third of the stars are binaries.

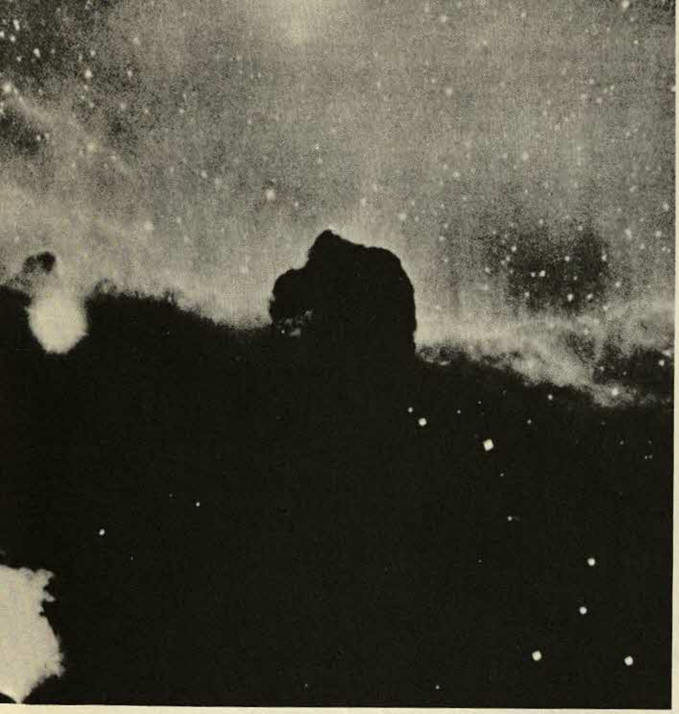
It is quite possible that the light which all stars give out varies slightly from time to time. However, the brilliance of some stars varies greatly. Exploding stars called ***novae*** are variable stars. They are dense white stars that rapidly increase thousands of times in brilliance and then become so faint they can no longer be seen. Other variables called ***Cepheids*** (SEF-ih-idz), change regularly in brilliance because they pulsate. Polaris is a Cepheid.

Groups of stars which are close together and appear to be moving together are called ***star clusters.*** There are several hundred star clusters in earth's Galaxy. The star cluster shown below contains about 50,000 stars, most of which are located in a space thirty light years wide. There are 10,000 times more stars in this space than in an equal space in other parts of the sky. This cluster, called ***Hercules,*** is 34,000 light years from the earth.

Mount Wilson and Palomar Observatories

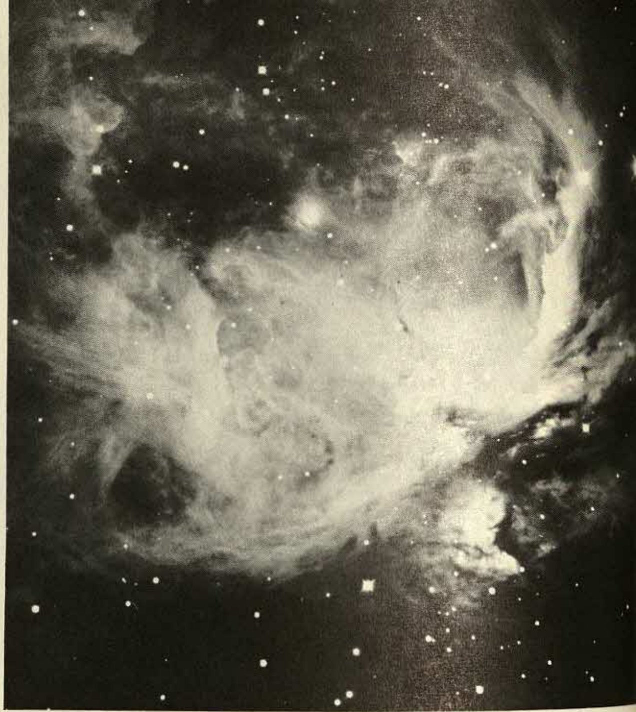


The globular star cluster Hercules contains more than 50,000 stars. Its diameter is around 100 light years, but most of its stars are in core thirty light-years wide.



Mount Wilson and Palomar Observatories

The Horse-head Nebula in Orion is one of the most striking of the dark nebulae in the sky.



Yerkes Observatory

The Great Nebula in the constellation Orion is a large mass of gases and dust particles.

Nebulae

In addition to stars, there are clouds of gas and dust in various parts of the Galaxy. Some of these glow brilliantly from the light of stars that lie within, or near, them. They are called ***nebulae*** (NEB-yoo-lee) from the Latin word for clouds. Some nebulae have no stars near them and are dark. The dark nebulae may cut out the light from bright nebulae. One of the most interesting of the dark nebulae is the Horse-head Nebula in the constellation Orion shown at top left. At the right is the Great Nebula of Orion.

SUMMARY

The sun, although it is 93,000,000 miles from the earth, is our principal source of energy. From careful observation astronomers have been able to describe many interesting features of the sun. The source of its tremendous energy is the nuclei of atoms. The nuclei of hydrogen atoms form nuclei of helium atoms. In this process, some nuclear matter is changed into energy.

The sun is only one medium-sized star among billions of stars in earth's Galaxy. It is believed that there are billions of other galaxies in the universe.

Stars have been named and classified in terms of size, color, brilliance, and the way in which they appear to be grouped in the sky.

In addition to stars, there are clouds of gas and dust in various parts of the Galaxy, which are called nebulae.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes the meaning of each statement.

1. The distance of the nearest star from the earth is (a) 10 light years (b) 4½ light years (c) 40 light years (d) 93,000,000 miles.

2. The number of chemical elements which have been identified on the sun is about (a) 2 (b) 60 (c) 102 (d) 20.

3. Sunspots appear black on the surface of the sun because they are (a) cooler than the surrounding surface (b) made up of black carbon (c) hotter than the surrounding surface (d) gaseous.

4. The nuclei of atoms which produce the energy of the sun are (a) hydrogen (b) carbon (c) oxygen (d) nitrogen.

5. The outermost layer of the sun's atmosphere forms (a) solar prominences (b) solar flares (c) corona (d) photosphere.

6. Streams of charged particles originating in the sun are believed to cause (a) nebulae (b) the aurora borealis (c) the coronagraph (d) binaries.

7. The star system in which the sun and its planets are located is called earth's (a) star cluster (b) binary (c) corona (d) Galaxy.

8. When Vega is referred to as Alpha Lyrae, it means that Vega is (a) a planet in the solar system (b) a constellation of stars (c) our nearest star (d) the brightest star in its constellation.

9. The color of stars having the highest temperature is (a) white (b) blue (c) red (d) yellow.

10. Stars whose brilliance changes greatly from time to time are called (a) suns (b) binaries (c) variables (d) planets.

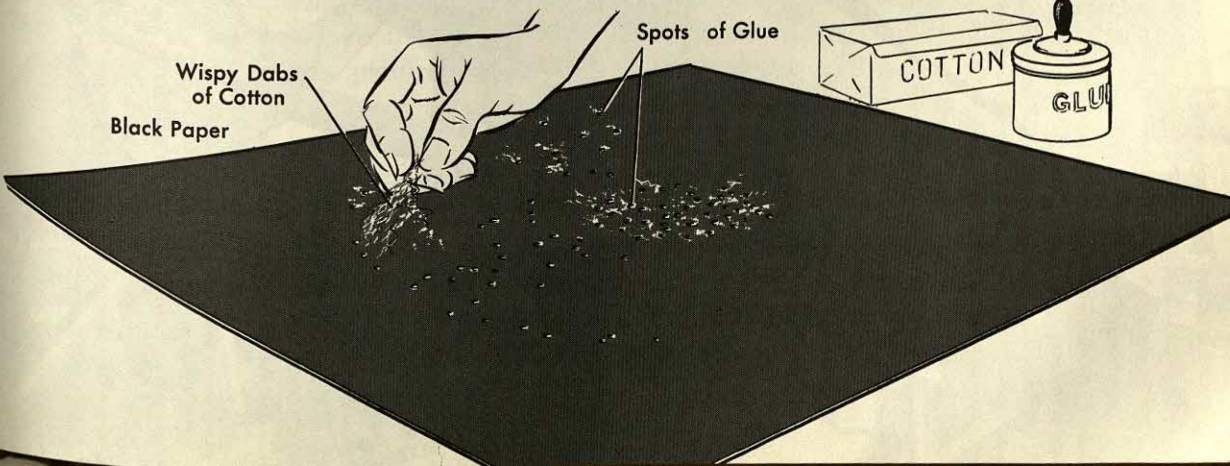
B. Preparing Demonstrations and Exhibits

1. By rotating a large ball, show how spots on the sun can be used to determine the sun's period of rotation.

2. Prepare a demonstration to show that there is energy in tides. Explain why it cannot be said that this energy comes principally from the sun.

3. Prepare a demonstration to show that energy from the sun is stored in foods. Foods such as butter and nuts can be used.

4. You can show what the Milky Way looks like by placing thin dabs of white absorbent cotton on black paper.

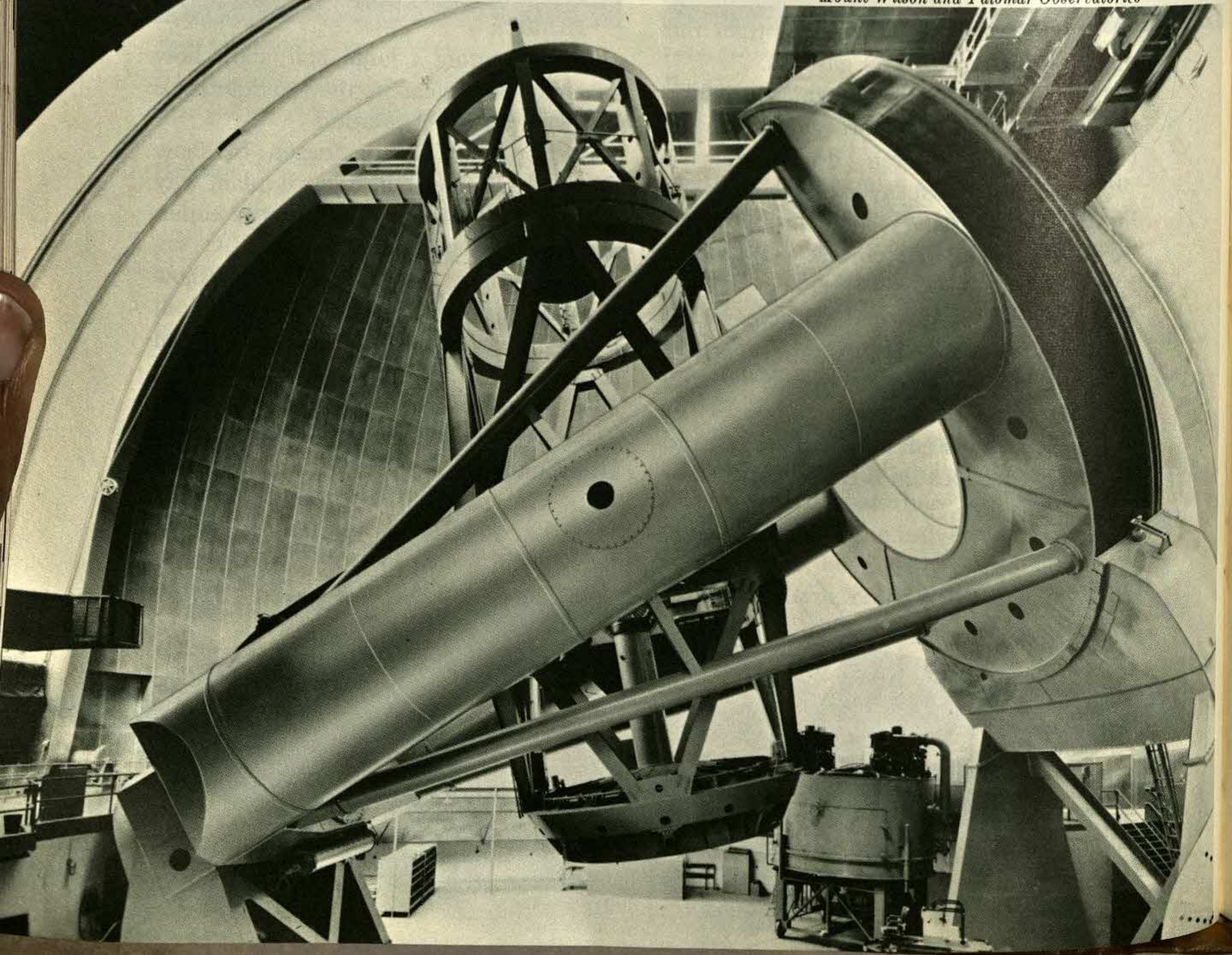


PROBLEM 5: HOW ARE SCIENTISTS ATTEMPTING TO EXTEND THEIR INVESTIGATIONS INTO SPACE?

From the time of Copernicus, man has come a long way in his efforts to describe and explain the universe. This progress has been made possible through the creative imagination of such men as Kepler, Newton, and the many others who followed them. To explain what they observed, they invented systems based upon the carefully recorded observations of the motions of celestial bodies. However, these great thinkers could not have developed man's present ideas of an orderly universe without the development of instruments for observation. You will recall how Galileo had to have the telescope to prove that planets such as Jupiter had other bodies revolving around them. In fact, bigger and better telescopes have been extending man's fields of exploration into space. Without these instruments, he might still be living in Copernicus' small, uncertain universe.

The 200-inch Hale telescope at Palomar Observatory is the largest reflector-type in the world.

Mount Wilson and Palomar Observatories



LIGHT TELESCOPES

You probably have looked at some distant object through field glasses. The object appeared much nearer than it did to the naked eye because the lenses in the field glasses magnified it.

Refracting Telescope

One kind of telescope, the refracting telescope, is constructed very much like field glasses. Its lenses are larger and gather more light. They also make distant objects appear to be much closer. The largest refracting telescope, with a lens forty inches in diameter, makes objects such as the moon appear 2,000 times as large as they look to the unaided eye.

Reflecting Telescope

It has been found impractical to make a refracting telescope with a lens larger than forty inches in diameter. For greater light-gathering ability, therefore, the reflecting telescope is used. Instead of having lenses through which light passes, the reflecting telescope has large mirrors. These mirrors reflect light from distant stars into an eyepiece from which they can be observed, or into a camera. The largest light telescopes in use today are reflecting telescopes.

The 200-inch reflector on Mount Palomar in southern California is the world's largest light-gathering telescope. It weighs over 500 tons and it took fifteen years to build. In the picture on page 326, you can see the size of this instrument.

With the 200-inch telescope, eight times as much space in the universe can be explored as with any other telescope. Its light-gathering power is four times that of the next largest. It can collect 640,000 times as much light as the human eye.

OTHER INSTRUMENTS

Many important discoveries could not have been made without cameras attached to telescopes. In fact, Dr. Ira Bowen, who is in charge of the 200-inch Hale telescope, has said that the telescope should really be called a 200-inch camera.

Because a photographic plate or film in the camera may be left exposed for minutes, or even hours, to the very faint light coming into the telescope from a distant star, a star which cannot be seen by the human eye shows on the photograph. Photographs are permanent records of stars. They are more accurate than drawings and written descriptions.

The spectroscope is another valuable instrument for exploring heavenly bodies. The spectroscope contains a triangular-shaped piece of thick glass called a ***prism.*** When sunlight which has passed through a prism falls on white paper, the colors of the rainbow are seen on the paper. This rainbow effect is called the spectrum of sunlight. Every star has its own spectrum. By studying the spectrum of the star's light, scientists can determine by the *if-then* method the chemical composition of the star, the speed at which the star is moving toward, or away from, the earth, and its temperature.

The coronagraph is one of the most valuable instruments for studying the sun. With it the astronomer, as you learned in Problem 2, page 299, can photograph the outer fringes of the sun.

Photo by Fritz Goro (Life Magazine)

The radio telescope above gives scientists an additional "window" through which to look at the stars. Antenna captures the radiant energy of radio waves given off by about 200 stars.

Other instruments measure the exact positions of stars, the diameters of stars, and the amount of light they give off.

RADIO TELESCOPES

Strange hissing radio noises, which seemed to come from nowhere here on earth, caused certain astronomers to wonder if these sounds could be produced by stars in outer space. Radio telescopes similar to the one shown above were built and used for radio observation of the suspected stars. Many sources in space, including our sun, were discovered to be giving off radio waves. The discovery of radio sources in space opened up an entirely new way of studying the universe.

There are many different types and sizes of radio telescopes. Some look like big dishes, while others look like wire fences. Each is designed for use in a special way.

The radio telescope will lead to many new discoveries. Already it has located objects that had never been seen with light telescopes. Although the surface temperature of the sun is 6,000°K, its corona has been found by the radio telescope to have a million-degree temperature. Thus new instruments add to man's knowledge about the universe.

OBSERVATORIES

The places in which astronomers work are called ***observatories.*** Most observatories are equipped with several types of telescope, as well as many other useful instruments. It costs millions of dollars to construct and equip these observatories, and thousands of dollars are spent annually to operate them. Generally, the astronomers of each observatory specialize in a certain kind of study.

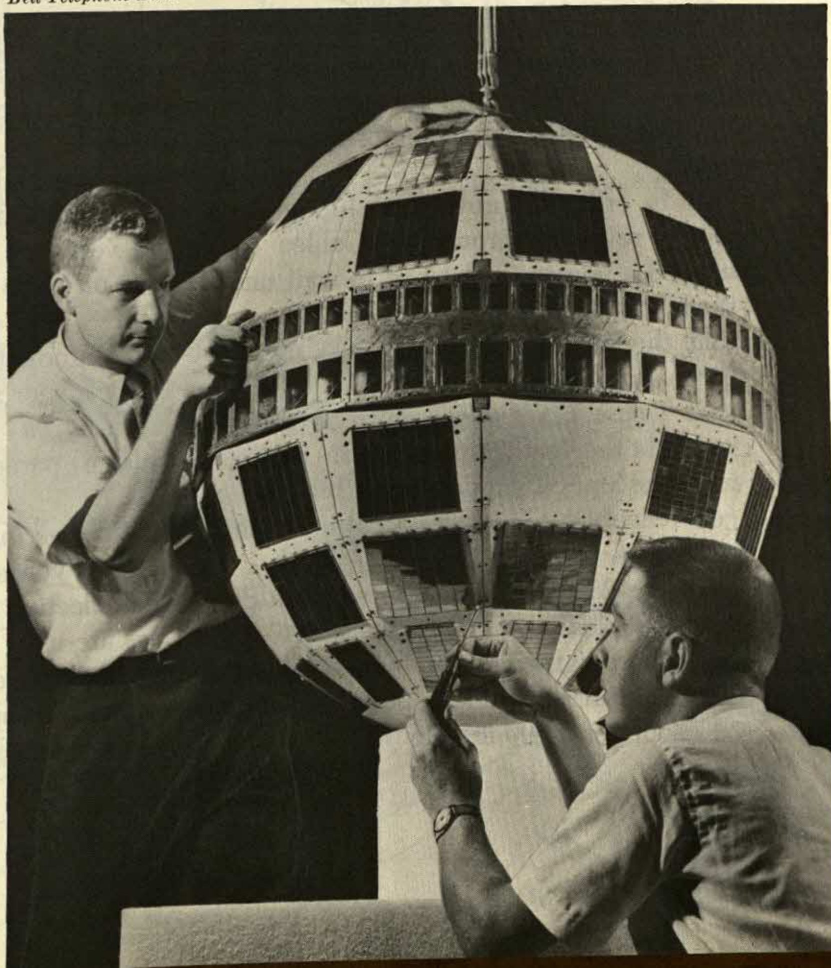
SPACE EXPLORATIONS

The earth's atmosphere has served to protect man from harmful radiations. It also contains gases essential for life. It is the transportation system which distributes water over the earth. In these ways, the atmosphere is most essential to man's existence. But the atmosphere has limited man in his attempts to explore the universe.

Rockets and satellites are now being used to overcome this limitation. Scientists are using them to carry instruments to probe beyond the earth's atmosphere.

The satellites are equipped with radio transmitters. These transmitters broadcast a radio signal beacon which makes it possible to track them from the earth. They

Bell Telephone Lab.



Communications satellite at the right has thousands of man-made sapphires covering its surface. These sapphires are designed to protect solar cells made of silicon wafers from space radiation. With such protection, it is hoped that this "working" telephone satellite will be able to endure the rigors of space travel for at least ten or more years.

also broadcast the observations made by their instruments. Broadcasting of this information is called ***telemetering.*** It employs a radio code which operates either by varying the duration of radio signals, or by varying the frequency of the signals. How satellites and other space probes are launched and the kinds of information obtained by them is explained in Unit 10.

SUMMARY

Astronomers could not have developed man's present ideas of an orderly universe without instruments to extend their vision into space. By using mirrors and lenses, man has developed telescopes that collect hundreds of thousands of times more light than the human eye can collect.

A number of instruments which have been developed for use with the light telescope have enabled man to improve the accuracy of his observations of the stars and other planets.

Radio telescopes and artificial satellites are being used to extend man's vision beyond the interference caused by the earth's atmosphere.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes the meaning of each statement.

1. In order to prove that Jupiter has moons revolving around it, Galileo (a) needed a telescope (b) had to wait until there was a solar eclipse (c) had to prove that the earth had a moon (d) used a coronagraph.

2. Telescopes that use mirrors to control light they gather are called (a) refracting telescopes (b) deflecting telescopes (c) reflecting telescopes (d) inspecting telescopes.

3. The 200-inch telescope (a) is a deflecting telescope (b) collects 640,000 times more light than the human eye (c) is the largest radio telescope in the world (d) contains a 200-inch lens.

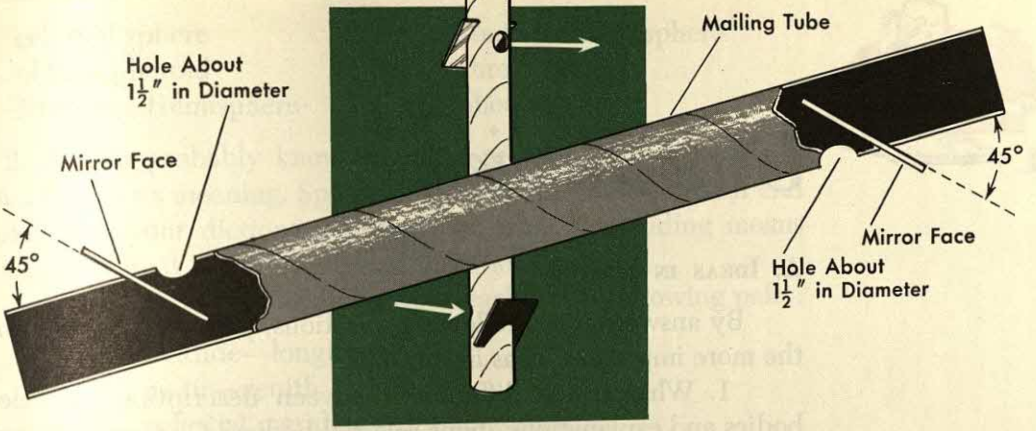
4. An instrument that contains a prism which breaks up light into its different colors is called a (a) telescope (b) microscope (c) bioscope (d) spectroscope.

5. Radio telescopes can be used to study objects in space because the objects (a) are very hot (b) are near the earth (c) give off radio signals (d) do not give off light.

6. Information collected by instruments in rockets or satellites is sent back to the earth by (a) radio signals (b) light signals (c) parachute (d) other rockets.

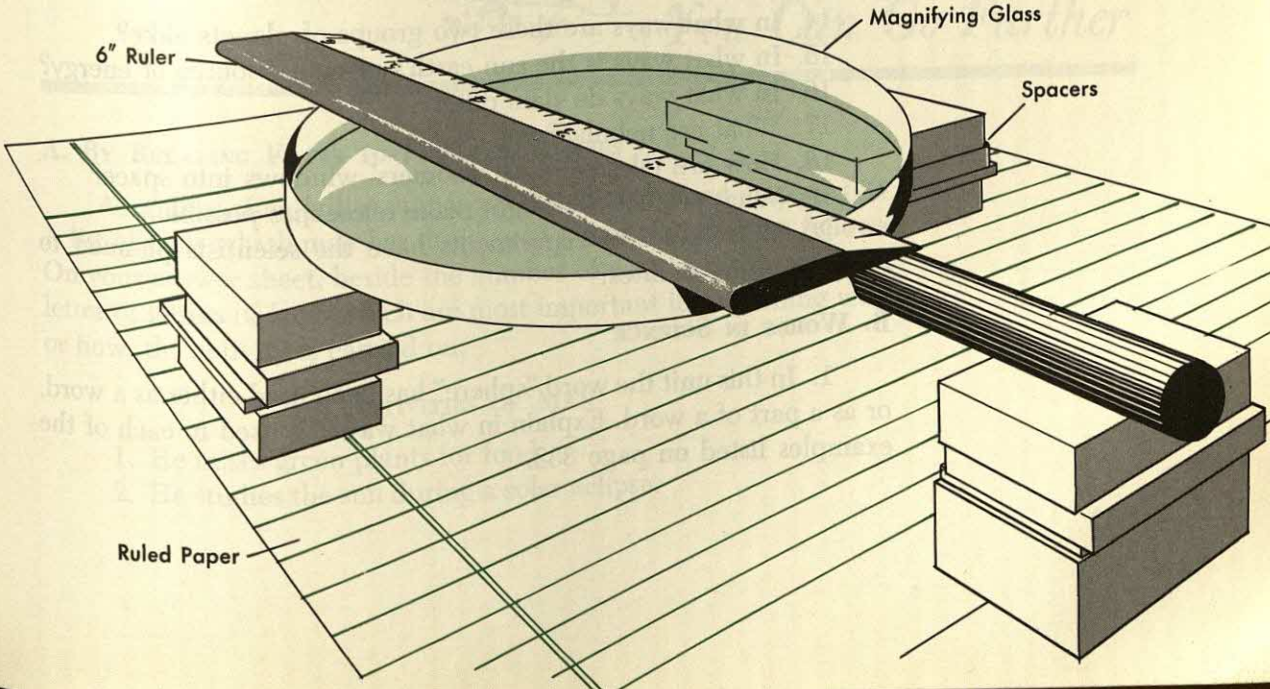
B. Conducting Demonstrations

1. As you can see from the diagram of the reflecting telescope on page 190, mirrors are used to gather light from distant stars and direct it through the eyepiece of the telescope. You can show how mirrors can be used to do this.



Obtain a mailing tube about two inches in diameter and two feet long. About three or four inches from each end of the tube, cut slits at angles of exactly forty-five degrees, as shown. Insert a pocket mirror into each slit. The top mirror should be placed mirror-side down; the bottom one should be placed mirror-side up. Cut a round hole about one-and-a-half inches in diameter directly opposite the top mirror and a smaller hole for an eyepiece directly opposite the bottom mirror. Use the tube to observe a lighted candle and other objects. Explain how the light enters the tube and is controlled within it so that you can see the image by looking in at the lower end of the tube.

2. Demonstrate the magnifying power of a lens by holding a hand lens in focus over ruled paper. Measure the width of one line and space on the paper and compare these measurements with those observed through the hand lens. Have several members of the class repeat the observation and record their results. How much wider is the magnified image of the lined space?



Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the more important ideas in this unit.

1. What is the difference between descriptions of celestial bodies and explanations about celestial bodies? Give some examples.
2. How are positions of different places located on earth?
3. How is the celestial sphere used to find positions of stars?
4. How was the Ptolemaic system used to explain the movement of planets?
5. How did Newton's laws help to explain the movement of planets?
6. Why is the earth called an oblate spheroid?
7. What are some effects of earth's rotation and revolution?
8. Why is it necessary to have time zones?
9. Why is moon rise forty-eight minutes later each night?
10. What is it like on the moon?
11. How is the earth affected by the moon?
12. How are comets and meteors related?
13. In what ways are the terrestrial planets different from the Jovian ones?
14. In what ways are these two groups of planets alike?
15. In what ways is the sun earth's principal source of energy?
16. In what ways do stars differ?
17. What are nebulae?
18. How are telescopes astronomers' windows into space?
19. What properties of light make telescopes possible?
20. What kinds of experiments have the scientists planned to carry on with satellites?

B. WORDS IN SCIENCE

1. In this unit the word "sphere" has been used either as a word, or as a part of a word. Explain in what way it is used in each of the examples listed on page 333.

celestial sphere
oblate spheroid
Northern Hemisphere
Southern Hemisphere
chromosphere
photosphere

2. As you probably know, the way in which a word ends is often a clue to its meaning. Spheroid, asteroid, and planetoid all end in "oid." Use your dictionary to find out what this ending means and explain why it is used in each of these words.

3. Explain the relationship between each of the following pairs:

latitude—longitude
nadir—zenith
celestial meridian—prime vertical
ellipse—circle
polar diameter—equatorial diameter
perihelion—aphelion
rotation—precession
winter solstice—summer solstice
perigee—apogee
solar eclipse—lunar eclipse
meteor—meteorite
aurora borealis—aurora australis

You Can Go Further

A. By Relating Facts to Man's Activities

A number of activities of man are listed below and on page 334. A list of facts which man has discovered about the universe follows. On your answer sheet, beside the number of each activity, write the letter or letters of facts which are most important in explaining why, or how, the activity is carried on.

Activities of Man

1. He raises green plants for food.
2. He studies the sun during a solar eclipse.

3. He states that Halley's comet will be nearest the earth again on April 29, 1986.
4. He moves the hands on his watch ahead as he travels.
5. He selects warm clothing suitable for winter.
6. He hangs clothes in the sun to dry.
7. He places his telescopes on mountain tops.
8. He uses daylight-saving time in the summer.
9. He uses a compass to locate directions.
10. He uses sunlight to take pictures with a camera.
11. He puts satellites into orbit around the earth.
12. He predicts the time of high and low tides.
13. He measures distances on the earth in degrees.

FACTS ABOUT THE UNIVERSE

a. The movements of celestial bodies can be accurately predicted by man.
b. Gravitational forces exist between celestial bodies.
c. The earth is an oblate spheroid.
d. The earth rotates on its axis.
e. The earth revolves around the sun.
f. The earth's axis is tilted 23½°.
g. The earth receives radiant energy from the sun.
h. The earth's atmosphere screens out some radiation from other celestial bodies.
i. Sometimes the moon casts a shadow upon the earth.
j. The earth has a magnetic field.

B. BY INCREASING YOUR KNOWLEDGE

1. Prepare a report on one or more of the following topics:
   a. Early Astronomers
   b. Astrology Today
   c. The 200-Inch Telescope
   d. The Schmidt Telescope
   e. Man-Made Satellites
   f. A Rocket Trip to the Moon
   g. Sunspots
   h. Astronomy as a Vocation
2. Conduct a discussion on "The Value of Astronomy to Man."
3. Draw diagrams of the following:
   a. A reflecting and a refracting telescope
   b. Great circle routes flown in transcontinental flights

4. Describe the appearance of the moon as seen through a pair of field glasses.

5. Prepare a bulletin board exhibit of the following:
   a. The 200-inch telescope and some pictures taken with it.
   b. Several constellations as they would appear in the sky. Use small white buttons for the stars and blue paper for the sky.
   c. The different ways in which the earth is affected by radiant energy from the sun.
   d. The use of man-made satellites and space probes to explore beyond the earth's atmosphere.

6. Visit an observatory to find out how astronomers work.

7. Collect a list of superstitions and misconceptions about the effect of heavenly bodies on man.

8. Prepare a superstitions-and-misconceptions test to be given to other classes. Compare the test results obtained.

9. Prepare a quiz program on facts about the universe and present it during a school assembly.

10. Visit a planetarium to observe one of the demonstrations. Planetariums usually sponsor programs for amateur astronomers.

C. By Reading

Adelman, Benjamin. *The Junior Astronomer.* 310 Livingston Terrace, S.E., Washington 20, D.C.

Annual subscription at moderate cost.

American Academy of Science Publications. *I.G.Y. and Astronomy Bulletins.* Washington, D.C.

List of publications available.

American Museum-Hayden Planetarium. *Star Explorer.* New York, N.Y.

Can be used to help you locate important constellations, stars, and planets.

Cleveland Museum of Natural History. *A Guide to the Stars.* Cleveland, Ohio.

National Science Teachers Association. *Science Materials.* 1201 Sixteenth Street, N.W., Washington 6, D.C.

Lists available science materials for young people.

Neeley, Henry M. *The Stars by Clock and Fist.* New York: The Viking Press, 1956.

Explains how an imaginary clock face can be used to locate positions on the horizon and how your fist can be used to measure the altitude of stars and planets.

Goro from Monkmeyer

U. S. Dept. of Commerce, Weather Bureau

UNIT 7

Weather and Climate

For many years, weather scientists, or meteorologists, have been collecting facts about the weather from a number of different places. But facts alone do not explain the weather.

Meteorologists believe that weather facts are related to each other in somewhat the same way that pieces of a jigsaw puzzle are related to other pieces. The jigsaw puzzle is not solved until each piece is in its place. Although meteorologists have ideas about how some of the facts are related, they have not completely solved the weather puzzle. The puzzle which they are trying to solve covers an area as large as the earth itself. It is as deep as the ocean of air that surrounds the earth.

Meteorologists want to solve the weather puzzle for two reasons. First, they want the satisfaction that comes to all scientists when they can explain how facts about such things as weather are related. Secondly, once scientists can explain weather, it will be possible for them to predict more accurately than is possible at the present time. Because of the many ways in which man's life is affected by the weather, it is important that the meteorologists be able to predict weather accurately several days ahead.

Luoma from Monkmeyer

Atmosphere determines weather, and clouds indicate condition of the atmosphere above the earth.

PROBLEM 1: HOW ARE DIFFERENT KINDS OF WEATHER PRODUCED?

Anyone can forecast weather on the moon because the moon has no atmosphere. As you learned earlier, there is neither wind nor rain there. Days on the moon are very hot and nights are very cold. It has only two kinds of weather—hot on the side facing the sun and cold on the opposite side.

Weather on the earth is a very different story. There are winds and rain on the earth. Sometimes the winds are gentle and at other times they are violent. There are cold days and hot days, cold nights and hot nights. Because the earth has an atmosphere, its weather is very complicated. Before you can ever hope to understand the weather, you must know something about the atmosphere—what it is and how it changes.

THE ATMOSPHERE

Air, a mixture of several different gases, behaves the same way as other gases.

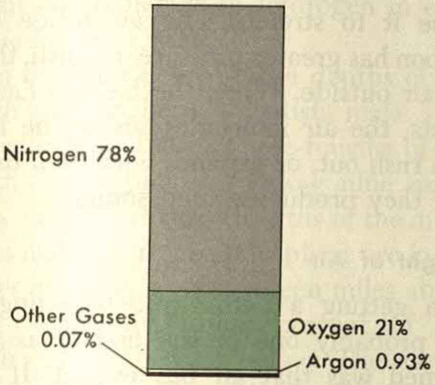
Movement of Air

The molecules of the different gases in the air are always moving. They move in all directions. As each molecule moves about, it frequently collides with other molecules of air.

Because no one can see anything as small as air molecules, evidence that they are moving has been obtained indirectly. It has been obtained by observing the effects of air on other things. Have you ever seen small bits of material moving about in a strong beam of light? Some people call them sunbeams. If you have seen them, you will recall that the shiny particles appear to be moving about in many different directions. Actually, they are being bounced about as air molecules hit them.

Density of Air

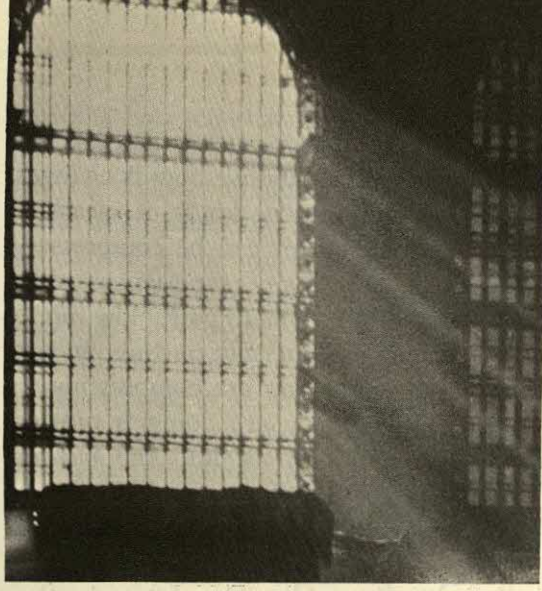
In Unit 2, you learned that this movement of molecules in a substance, such as air, increases as the temperature of the



Earth's atmosphere complicates its weather picture. The diagram above shows the various gases which make up this atmosphere.

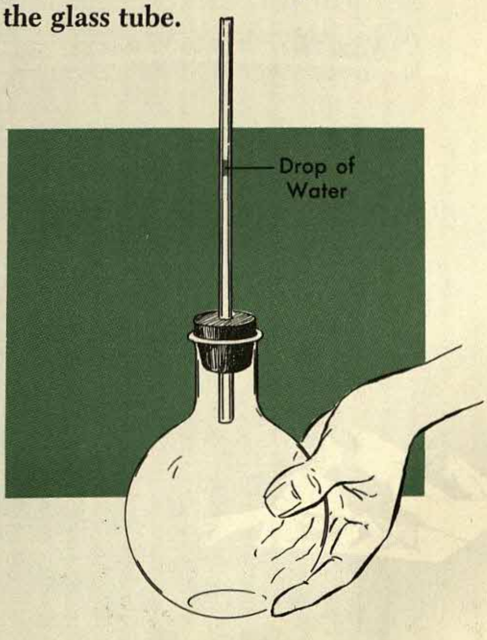
substance increases. Furthermore, as the substance is heated, the distance between the molecules becomes greater. For this reason, a gallon of warm air contains fewer molecules than a gallon of cold air. The density of warm air is said to be less than that of cold air. Or, to state it another way, cold air is said to be denser than warm air.

Here is something you can do to get evidence that molecules are moving about. Have someone hold an open bottle of household ammonia about three or four feet from your nose. Soon you will be able to smell the ammonia. You saw nothing leave the bottle, yet you know something must have left it and moved out where you could smell it. The idea that molecules of ammonia gas moved out from the solution in the bottle is used to explain the fact that you can smell it.


Jerry Fund—Monkmeyer

Particles seen bouncing about in sun's rays are being hit by moving molecules of air.

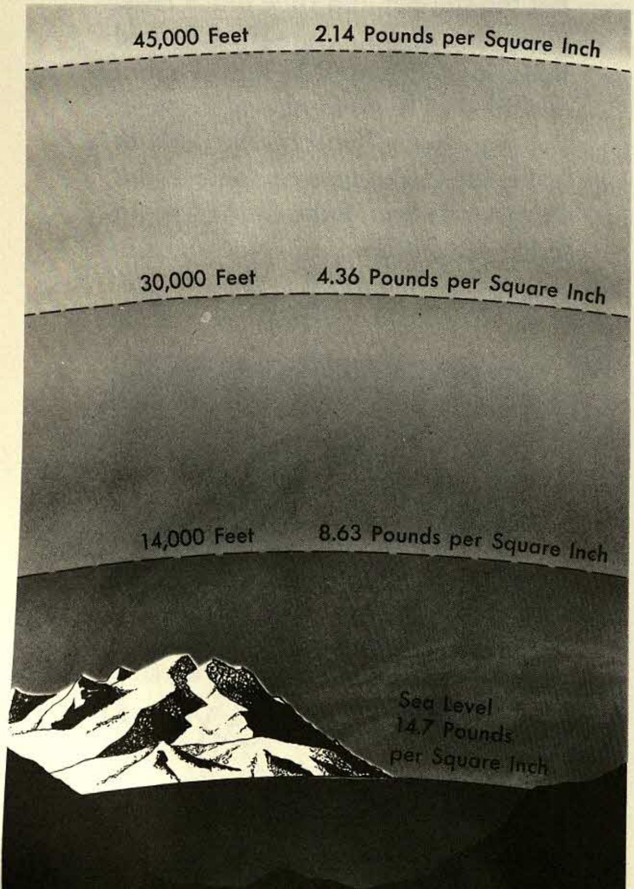
You can show how air expands when it is only slightly heated. Insert a glass tube about ten inches long through a one-hole stopper. Put the stopper and tube into a flask. Put a drop of water into the tube and shake it slightly so that it goes about one-third of the way down the tube. Put your warm hand on the flask, or bring the flask close to some warm object and observe the drop of water in the glass tube.



Compression of Air

Air has other properties which are important in understanding how it changes to give man different kinds of weather. Like other gases, air can be compressed. You have had many experiences with compressed air. When you blow up a balloon, you are not only putting air into the balloon, but you are compressing it. Actually, what you are doing is putting more molecules of air into the balloon than were in it before you blew it up. The molecules of air in the balloon are squeezed close together. They bounce around more rapidly. They hit each other with greater force. They also hit the sides of the balloon with greater force and cause it to stretch. The air inside the balloon has greater pressure, or push, than the air outside. When the balloon finally bursts, the air molecules inside the balloon rush out, or expand, with such force that they produce a loud sound.

The weight of air molecules causes atmospheric pressure. A cubic foot of air near sea level contains more molecules than a cubic foot at a high altitude. Thus, atmospheric pressure decreases with an increase in altitude.


45,000 Feet
2.14 Pounds per Square Inch
30,000 Feet
4.36 Pounds per Square Inch
14,000 Feet
8.63 Pounds per Square Inch
Sea Level
14.7 Pounds
per Square Inch

Weight of Air

In getting a better understanding of air, probably one of the first ideas you learned was that air has weight. It has weight because each molecule of its gases is being pulled by gravitational force toward the center of the earth. As you will recall from Unit 2, the gravitational force between two bodies (the earth and the molecules making up the air) depends, in part, upon the mass of the two bodies.

Depth of Air

The earth is big enough, that is, has enough mass, to hold around it an atmosphere hundreds of miles deep. If the earth had been as small as the moon, its gravity would not have held the atmospheric gases which were formed when it began to cool off. The earth would have had no atmosphere.

As the atmosphere is explored higher and higher above the earth, scientists are less willing to state that the atmosphere is a certain number of miles deep. The farther balloons and rockets travel from the earth the thinner (less dense) the atmosphere becomes. There seems to be no one place, however, where the atmosphere ends and space begins. Even at great distances beyond the earth, in areas called space, there seems to be a thin atmosphere. It has been estimated that there is about one molecule of hydrogen in each cubic meter of space.

In order to describe the depths of the earth's atmosphere, scientists make such statements as these. Three-fourths of the earth's atmosphere is below nine miles. This means that three-fourths of the molecules making up the atmosphere are in the lower nine miles. At nineteen miles above the earth, ninety-nine percent of the earth's atmosphere is below. The earth's atmosphere is one-millionth as dense at sixty miles above the earth as it is at sea level. This means that the distance between molecules is a million times greater sixty miles above the earth than it is at sea level.

Atmospheric Layers

From the previous discussion, you might get the impression that the only way in which the atmosphere changes at increasing distances from the earth is to get thinner. Actually, it has several layers, each of which is different from the others.

If you have ever gone up in an airplane, or driven to the top of a high mountain on a warm day, you know that the air is cooler the higher you go. In general, the temperature of the air is 1°F lower for each 300-foot increase in altitude. Recent observations in the Antarctic, however, have shown that the temperature there rises as altitude increases. The temperature 1,000 feet above a layer of ice in the Antarctic may be 50°F higher than it is at sea level.

Until about sixty years ago, though, it was thought that air temperature would continue to decrease the higher you went. In 1900, two scientists found that this is not true. They made their discovery by sending balloons to higher altitudes. They found that, after about seven miles, the air no longer continues to get colder. In fact, there is a layer between about seven and thirty-five miles where the air temperature stops dropping as you go higher. It either rises, or remains the same. This layer is called the ***stratosphere.*** "Strato" means a spreading. It is a layer of air which spreads out over the ***troposphere,*** the layer of atmosphere in which man lives. "Tropo" means a turning or changing. The troposphere is also the layer in which our weather is made.

The boundary surface between the troposphere and the stratosphere is called the ***tropopause.*** It is higher at the equator and lower near the poles.

Beyond the stratosphere are other layers of the atmosphere. The ***mesosphere,*** which extends to a height of about fifty miles above the ground, is a layer in which temperature rises to a maximum. From there, another layer, called the ionosphere, extends outward about 250 miles. At this level, the air is extremely thin. The scattered air particles become ***ionized*** by cosmic rays knocking electrons out of them. As you will recall from Unit 4, the ionosphere makes it possible to receive radio signals from beyond the horizon. The particles of air in the ionosphere are very hot. In some parts of it, temperatures go as high as 1,500°F.

The extremely thin layer beyond the ionosphere is called the ***exosphere.*** Bombardment by cosmic rays in this layer is intense. Ions in this layer become much hotter than ions in the ionosphere.

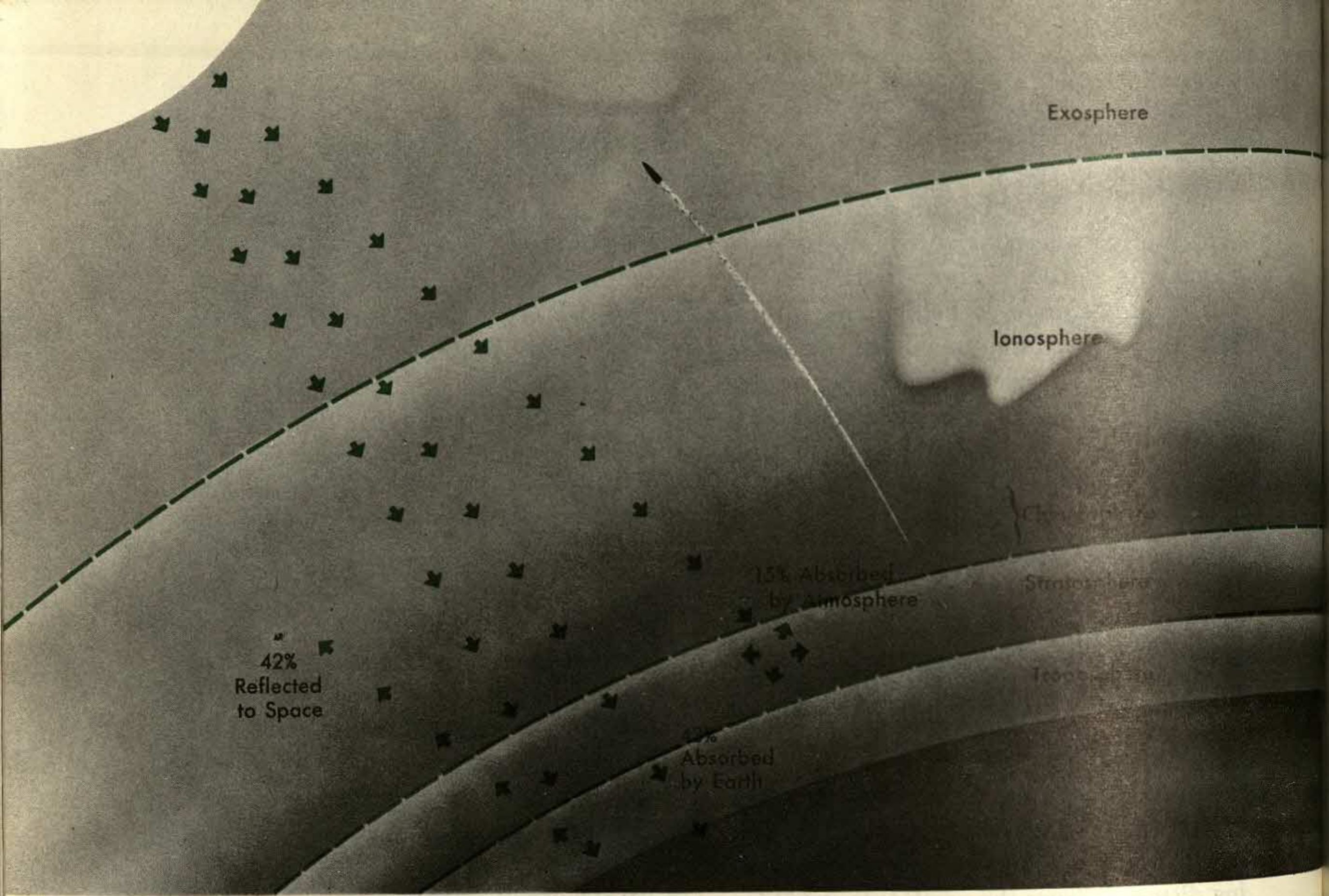


Diagram shows what happens to radiant energy which reaches the earth from the sun each day.

Warming the Troposphere

It has been estimated that only forty-three percent of the radiant energy which reaches the earth from the sun gets through to the earth's surface. What happens to the rest is shown on the diagram on this page. The radiant energy that reaches the surface of the earth warms it. The earth, in turn, heats the air near it by conduction and radiation. The atmosphere near the surface of the earth is warmer than that farther above it.

The earth eventually loses as much heat as it receives. If it were not for the clouds, water vapor, and carbon dioxide in the air above the earth, heat would be lost so rapidly that the earth would be extremely cold at night. The radiant energy given off by the warm earth has a longer wave length than that which comes from the sun. The sun's short-wave rays pass through water vapor and carbon dioxide. However, the earth's longer waves are re-emitted back to the earth by these gases, which thus slow down the rate at which the earth loses its heat.

Several conditions affect the amount of heat produced at the earth's surface by radiant energy from the sun. The number of hours of daylight affects the amount of radiant energy which any part of the earth receives. Wherever there are clouds, dust particles, and smoke in the air, less radiant energy reaches the earth. When rays of radiant energy strike the earth at a slant, the surface is heated less than when they strike it directly. Dark-colored surfaces such as soils and rocks are heated more by radiant energy than light-colored surfaces. Water surfaces are heated more slowly by radiant energy than land surfaces. Because the earth has many different kinds of surfaces, some parts of the earth and the atmosphere above them are heated more than others.

WATER VAPOR

Moisture is constantly evaporating from bodies of water and moist surfaces of the earth. The air near the surface of the earth, therefore, contains the invisible gas, water vapor.

Condensation of Water Vapor

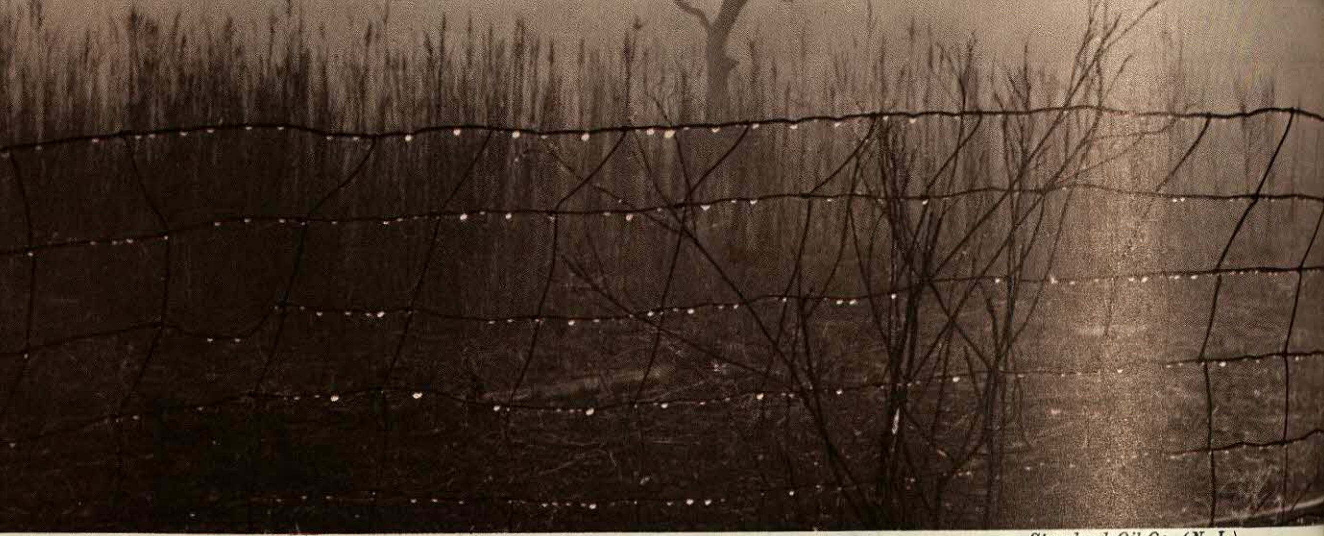
When the air is holding as much water vapor as it possibly can at a certain temperature, a very small drop in temperature may cause the water vapor to condense. On a warm, humid day you may have seen water vapor condense when the air touched something cold as, for instance, a pitcher of ice water. On a cold day you probably have observed water vapor condensing when the warm air you exhale mixes with the colder air outside your body. Or you may have seen condensation occur when the hot exhausts from jet planes formed vapor trails. Droplets of water are formed in the cold air. Droplets of water will form in the air only when there are very small particles of material such as dust, or smoke, suspended in the air. When there is very little water vapor in the air, the temperature will have to be lowered much more before it condenses.

The temperature at which water vapor will condense is called the ***dew point.***

Through the process of evaporation, the snow-banked stream, below left, gives up a great deal of water vapor to the air. On the other hand, the desert at right yields very little water vapor.

Canadian Pacific Railway

Union Pacific Railroad



Standard Oil Co. (N. J.)

An early morning fog in a Louisiana bayou condenses on a cold wire fence and forms dewdrops.

When the temperature of the air is lowered to its dew point, water may form a cloud or fog, or it may be returned to the surface of the earth in the form of dew, frost, snow, rain, or hail. Water that falls to the earth as rain, as snow, as sleet, or as hail is called *precipitation.*

Fog, Dew, and Frost

The cooling of a large body of air near the surface of the earth to a temperature below its dew point may result in a *fog.* A fog is formed when the invisible water vapor in the air condenses on particles to form extremely small droplets which remain suspended in the air near the surface of the earth.

At night, plants, other objects, and the ground itself often lose much of their heat and become cooler than the surrounding air. When the temperature of these objects drops below the dew point of the air, water vapor in the air immediately surrounding them may condense as *dew* on these objects.

When the dew point of the air is below 32°F, water vapor in the air may change directly from a gas to solid ice crystals called ***frost.*** You can see this frost on the freezing unit in some refrigerators. Before frost will form on an object, temperature of the object must be below 32°F.

Clouds, Rain, and Snow

When rising air containing sufficient water vapor is cooled below its dew point, clouds may form. This happens only when there are particles in the air around which tiny droplets of water, or crystals of ice or snow, can form. The temperature determines whether droplets of water or ice crystals form.

Rain may result when droplets of water combine, or when warm air enters the cloud from below and water vapor in it condenses on droplets already present.

Have you ever stopped to think what it takes to produce a rainstorm? Here are some facts which will help you to understand what a remarkable event it is. One inch of rain, covering one square mile, weighs 72,300 tons. A one-inch rain covering the state of Colorado, which has an area of 104,247 square miles, would weigh 7,537,058,100 tons. These tons of water would have to be evaporated before they could get into the atmosphere. Once in the atmosphere, much of the water would probably have to be moved great distances in order to produce a rain over Colorado. The sun would provide the energy for this amazing task.

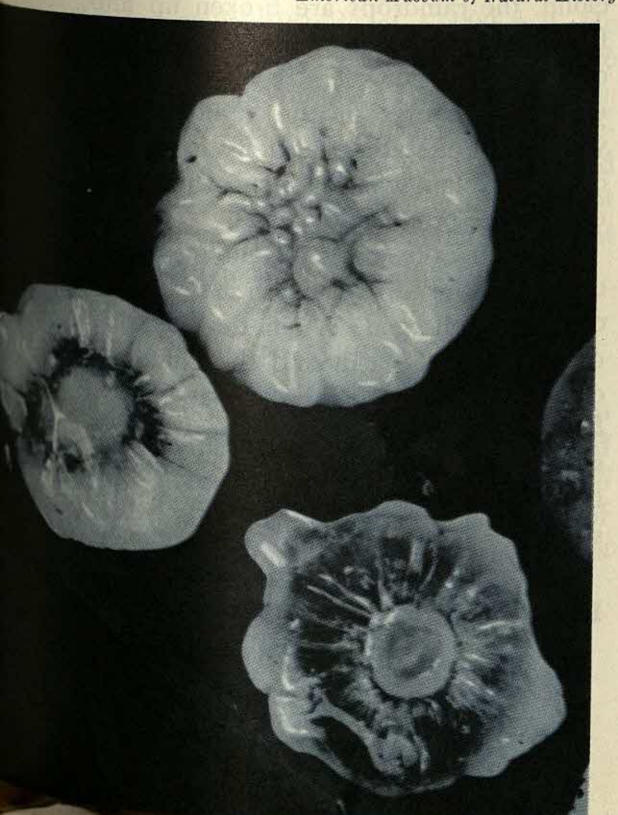
Tiny snow crystals grow when additional water vapor condenses on them. Rain or snow begins to fall only after the droplets, or flakes, become too heavy to remain suspended in a cloud.

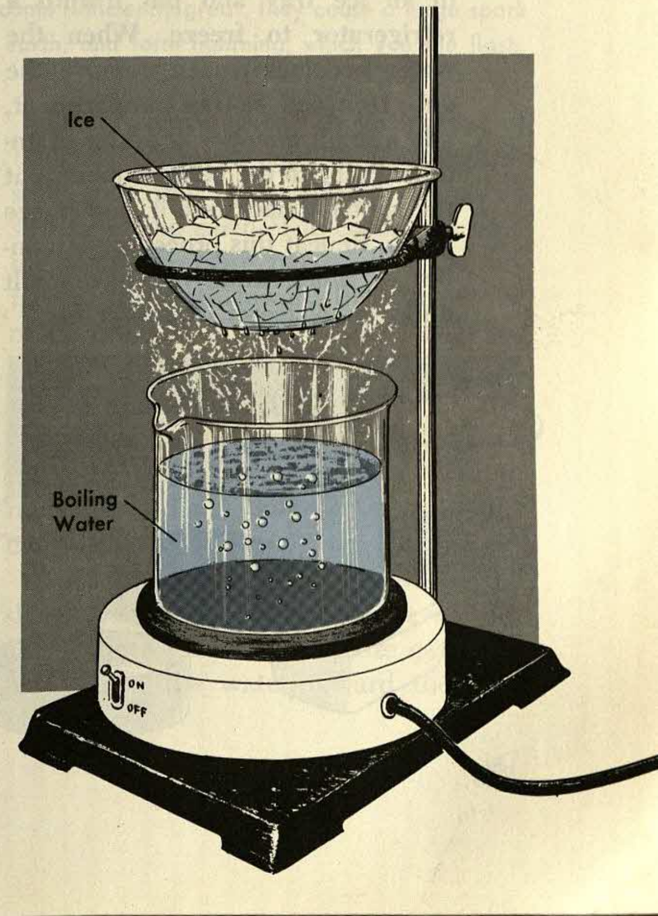
Before snow reaches the earth, air temperatures between the earth and the cloud must be cold enough to prevent snowflakes from melting as they fall. The air below the cloud must also be moist enough to prevent snowflakes or rain from changing back into water vapor.

Here is a simple demonstration in which you can observe evaporation, condensation, and precipitation. Place a large bowl of ice in a ringstand and set it directly over a pyrex bowl containing boiling water. You will see droplets of water form on the bottom of the cold bowl. Observe how the droplets get larger as more water vapor condenses. Soon they become so large that they fall back into the hot water. Can you think of other ways to demonstrate the evaporation-condensation-precipitation cycle?

Layers by which hailstones are built up show in these stones which have been cut apart.

American Museum of Natural History

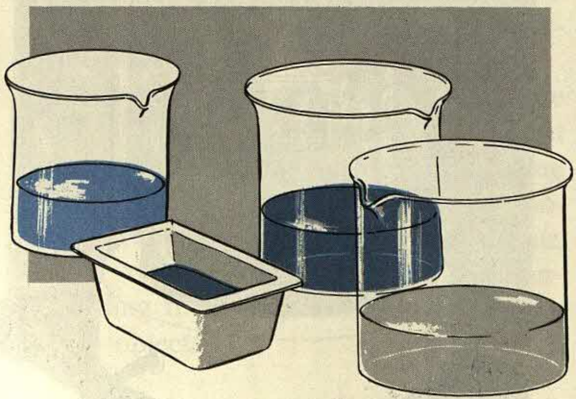




Hail

Hail is usually formed when large drops of water are carried from a lower to a higher part of a cloud where temperatures are below freezing. As each drop of water reaches the colder cloud levels, snow and frost are added to it. It then falls, but stronger currents of air may soon carry it up again to freezing layers of the cloud, where more snow and frost are added. Each time the growing hailstone falls and is returned to the colder part of the cloud, another layer of ice is added. When the hailstone becomes too heavy to be suspended by updrafts of air, it falls to earth.

By freezing water of different colors, you can show how the layers of a hailstone are formed. Place a small quantity of water of one color in an ice tray and put it into a refrigerator to freeze. When the water becomes frozen, remove the cube from the ice-tray compartment, add a small quantity of water of another color to the compartment, put the ice cube back into it, and freeze again. Repeat this procedure a number of times, until you have built up layers of ice of several colors.



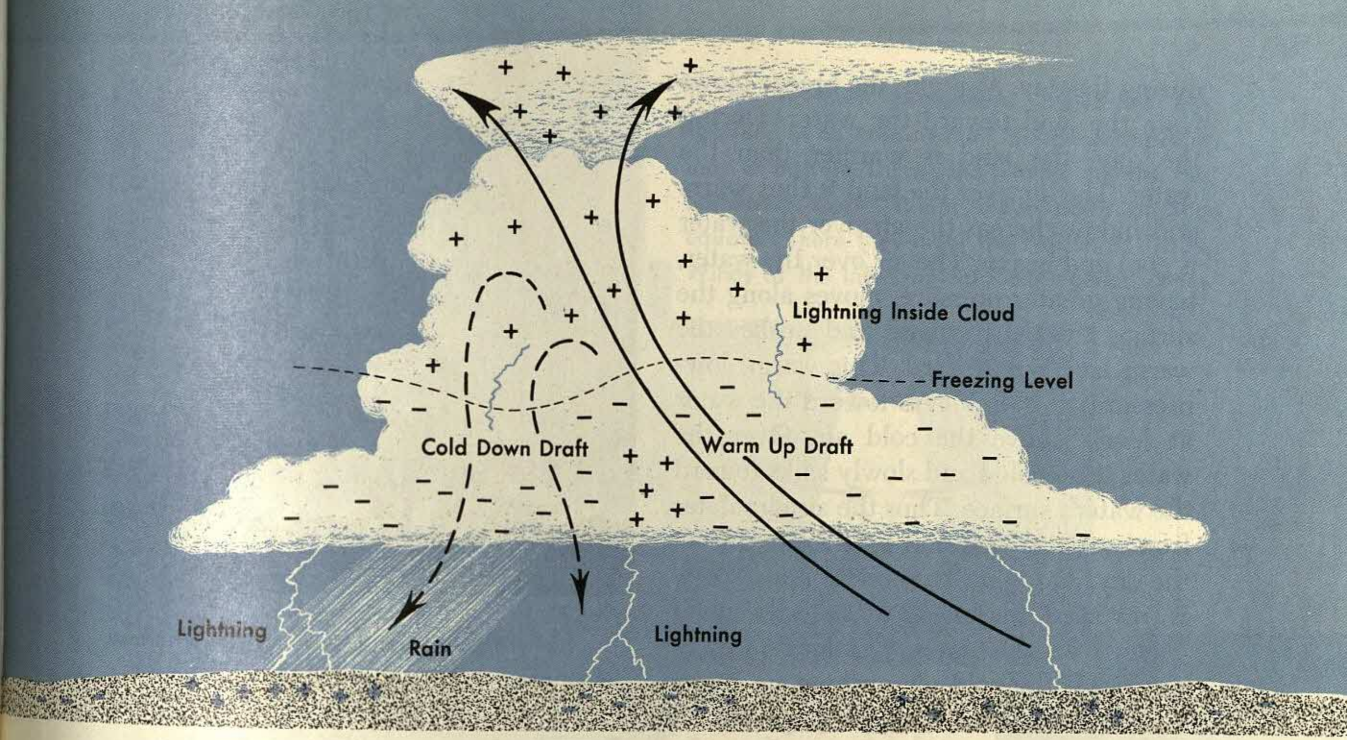
Thunderstorms

When the temperature of air near the surface of the earth is much higher than the temperature of the air above it, warm air containing much water vapor rises rapidly. What happens, actually, is that the colder air above it is pulled with greater force toward the earth. It, in turn, pushes up the warm air. The greater the difference in temperature, the more rapidly this turnover, or ***convection***, takes place. The cloud producing a ***thunderstorm*** develops from this rapid upward movement. Warm summer afternoons when the air contains considerable water vapor are the best times for the formation of clouds that may produce thunderstorms. A thunderstorm generally does not cover much territory. Lightning, thunder, rain, and, sometimes, hail accompany it.

The diagram on page 347 shows how the cloud becomes electrically charged. As rain forms in the upper parts of the cloud, the raindrops are broken up into finer particles by the strong upward rush of air from below. This produces static electrical charges in the clouds. From your study of static electricity in Unit 2, can you explain what happens when static charges are produced?

An electrically charged cloud may cause objects on the earth beneath it to become oppositely charged. When the electrical charges on the earth and the cloud become sufficiently great, a spark called ***lightning*** flashes between them. It is then said that lightning strikes. High buildings, trees, and other tall objects are more often struck by lightning than lower objects.

During the summer of 1959, a military pilot had to eject himself from his jet



When electric charges are built up on a cloud, as shown above, surface of the earth becomes positively charged. When charges on the cloud become sufficiently great, they cause a large spark to break through the air to another cloud, or to earth, and form lightning, which you see flash.

plane at an altitude of 47,000 feet. He parachuted into a thunderstorm, where updrafts kept him aloft for forty minutes. He was pelted by hail and rain and became airsick from being tossed up and down in the clouds. By the time he got out of the clouds and landed, his right hand had become frostbitten.

WINDS

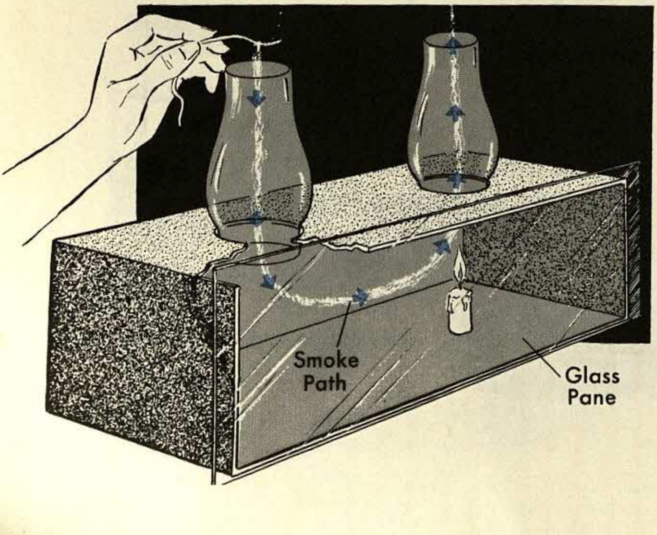
Whenever any land surface absorbs more radiant energy from the sun and thus becomes warmer than the surface of the land surrounding it, a movement of air results. This movement of air across the surface of the earth is ***wind.***

The air covering the cooler surface of the earth is heavier, and has greater pressure, than the air covering the warmer surface of the earth. The cooler air, having greater pressure, moves along the surface of the earth toward the warmer air of less pressure. If pressure differences between the two bodies of air are great, violent winds may result.

It takes longer for radiant energy to raise the temperature of water than to raise that of land. But since water holds more heat, it cools more slowly.

If you have spent much time along the shores of an ocean or lake, you have probably noticed that a cool breeze generally blows from the water toward the land during the day. At night, the breeze blows from the land toward the water. During the day, the land is warmer than the water. The air over the land is thus warm and light, whereas the air over the water is cool and heavy. The air over the water, having greater pressure, moves along the surface toward the land and pushes the warm land air upward. This warm, low-pressure air then moves toward the water at levels above the cold air. Over the water it is cooled and slowly sinks toward the water's surface. Thus the air circulates from water to land and back again during the day. At night, the direction of air flow is reversed because the land becomes cooler than the water. The movement of air caused by cold air pushing up warm air is called convection. See page 346.

You can demonstrate convection by using a box like the one in the diagram. If you don't have such a box, you can make one out of a shoebox. After the candle in the box is lighted, place it under one of the tubes. Now hold a piece of smoking string over the other tube. If you can observe this in a dark room, you will be able to see the convection.



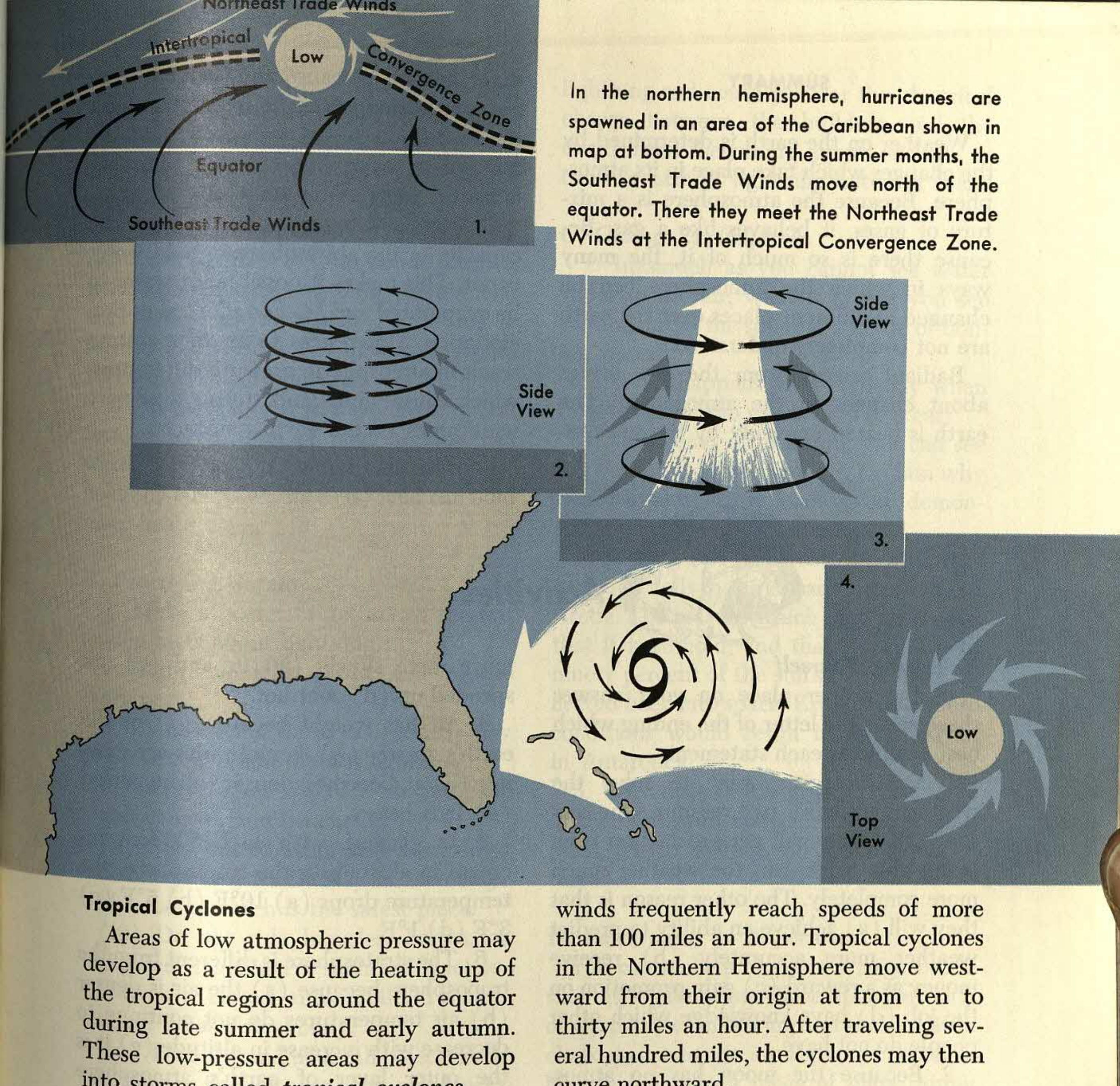
Wide World

This funnel-shaped cloud is typical of tornadoes, which occur in spring and early summer.

Tornadoes

If you have ever seen a little whirlwind, you have observed the forces that go to make up a ***tornado.*** Tornadoes are whirling storms made up of violent winds. They usually form in thunder clouds above the surface of the earth and in a manner not clearly understood. They first appear as funnel-shaped clouds which have the pointed end extending toward the earth.

A tornado's path is generally no more than a quarter of a mile wide and twenty to forty miles long. The tornado moves forward, usually in a northeasterly direction, at a speed of about thirty miles an hour and can damage an area a quarter of a mile wide and half a mile long in less than a minute's time. In the United States, tornadoes occur most frequently in the central and southeastern states during the spring and early summer. Can you explain why they occur at this time?



In the northern hemisphere, hurricanes are spawned in an area of the Caribbean shown in map at bottom. During the summer months, the Southeast Trade Winds move north of the equator. There they meet the Northeast Trade Winds at the Intertropical Convergence Zone.

Tropical Cyclones

Areas of low atmospheric pressure may develop as a result of the heating up of the tropical regions around the equator during late summer and early autumn. These low-pressure areas may develop into storms called ***tropical cyclones.***

In such cyclones, in the Northern Hemisphere winds revolve counterclockwise around the relatively calm air at the center of a low-pressure area. Counterclockwise is a direction opposite to that in which the hands of a clock move. The winds frequently reach speeds of more than 100 miles an hour. Tropical cyclones in the Northern Hemisphere move westward from their origin at from ten to thirty miles an hour. After traveling several hundred miles, the cyclones may then curve northward.

Tropical cyclones are called ***hurricanes*** in the West Indies, ***typhoons*** in the western Pacific, and ***cyclones*** in the Indian Ocean. They are destructive storms in which strong winds are accompanied by heavy rain.

SUMMARY

Weather on the earth is determined by the changes which take place in its atmosphere. Because the atmosphere is a mixture of gases, it behaves like a gas. Because there is so much of it, the many ways in which the atmosphere can be changed at different places over the earth are not completely understood.

Radiant energy from the sun brings about changes in the atmosphere. The earth is heated unevenly by the sun's radiant energy. Because the lower atmosphere is heated primarily by contact with the heated earth, the temperature of the atmosphere over different earth surfaces is not the same at any time.

Changes in temperature change the capacity of the atmosphere to hold water vapor. This makes it possible for water to be evaporated and later condensed as precipitation. Differences in air temperature result in atmospheric pressure differences, which cause winds and storms over very wide areas of the earth's surface.

Activities

A. *Testing Yourself*

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Meteorologists want to solve the weather puzzle for two reasons. One reason is that they will get satisfaction from being able to explain the weather much more completely. The other reason is that they will (a) achieve an ability to predict weather more accurately (b) receive money as a reward (c) gain promotion on the job (d) have knowledge which other people do not have.

2. Because the moon has no atmosphere, (a) temperatures do not change (b) it is easy to predict its weather (c) storms are worse there than they are on the earth (d) it receives less radiant energy than the earth.

3. When air is heated, its molecules (a) move more slowly (b) expand (c) are speeded up (d) contract.

4. Air has weight because (a) of the earth's gravity (b) its molecules are moving (c) it becomes denser when cooled (d) it is heavy.

5. In general, with each 300-foot increase in altitude in the troposphere, the temperature drops (a) 10°F (b) 5°F (c) 3°F (d) 1°F.

6. The stratosphere is different from the troposphere because (a) the air is denser (b) air temperatures do not continue to decrease with increase in altitude (c) it is the outer layer of earth's atmosphere (d) it is heated by contact with the earth.

7. Gases in the atmosphere that re-emit radiant energy back to the earth are (a) nitrogen and oxygen (b) carbon dioxide and neon (c) water vapor and carbon dioxide (d) nitrogen and water vapor.

8. Dew point is (a) a place where dew forms (b) the same as frost (c) the point at which no more dew is formed (d) the temperature at which water vapor in the air condenses.

9. When water vapor in the air condenses on particles to form visible droplets which remain suspended in the air near the surface of the earth (a) a fog is formed (b) it rains (c) dew is deposited (d) ice crystals soon form.

10. It takes longer to raise the temperature of water than of land because (a) water is colder (b) water can hold more heat (c) land is warmer (d) land can hold more heat.

B. Practicing Safety

1. Make a poster to get across the following facts about lightning.

a. Lightning kills about 400 people every year.

b. By observing these rules, death may be prevented when there is lightning.

(i) Avoid open spaces such as fields, golf courses, and beaches.

(ii) Stay out of attics and away from chimneys and walls. Stay in the center of a room, which is the safest place.

(iii) Do not ride bicycles, horses, or exposed machinery such as tractors. Stay in a closed automobile. You are safe if it has a steel body.

(iv) Do not stand near tall objects such as trees or flagpoles, or near wire fences and other kinds of metal objects, which are good conductors of electricity.

2. Lightning rods are safety devices put on buildings to protect them during thunderstorms. From what you have learned about electricity in Unit 5, explain how a lightning rod could prevent the electrical charge between the building and the cloud from becoming great enough to cause a flash of lightning between them.

C. Giving Explanations

1. Inasmuch as you cannot see water vapor in the air, what is it that you see coming out of the spout of a kettle of boiling water?

2. What happens on a cold day when frost forms on the windshield of a car?

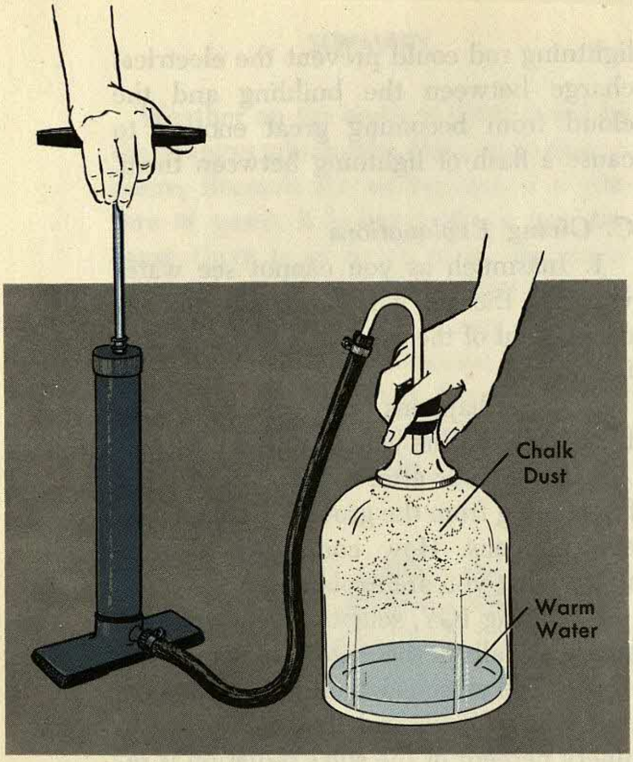
3. Sometimes after a rain, you can see fog coming from the ground. Explain why this happens. How could you demonstrate what you are explaining?

4. During IGY, scientists reported that less snow falls in the Antarctic than in the Arctic. The reasons which they gave were that it is so cold, and that eighty-five to ninety percent of the sun's radiation is reflected back into space. Explain how these conditions would result in less snowfall in Antarctica.

5. Why doesn't the gravitational force of the earth pull molecules together to a point where there is no space between them?

D. Performing an Experiment

You can make a cloud in a large bottle such as a gallon jug. Place about an inch of warm water in the jug and shake a little chalk dust into the air above it. Attach a bicycle pump to a piece of glass tubing running into the bottle through a stopper. Hold the stopper in place in the bottle and pump air into the bottle. After the air has been compressed in the bottle, the stopper will blow out when you remove your hand. Observe what happens then. If a good



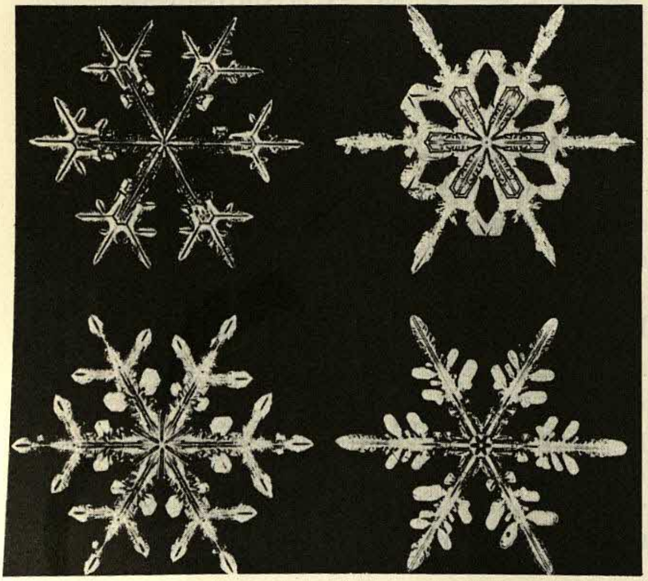
cloud does not form, add several drops of alcohol to the water and try the experiment again.

What happens in this bottle is very nearly what happens when clouds form in the atmosphere. Water vapor enters the air from the water in the bottom of the bottle. As the stopper blows out, the air expands. When the air expands, it cools. This cooling lowers the temperature below the dew point. Water vapor condenses on the particles of chalk dust and forms a cloud.

Now that you know how to make clouds, you can do experiments to answer such questions as: Do clouds form more easily with smoke, or with chalk dust? How does increasing the pressure in the bottle affect the cloud? At what temperature should the water in the bottom of the bottle be to make the best cloud?

Photomicrograph of snow crystals shows that while all are six-sided, no two are ever alike.

Courtesy of Bausch and Lomb Optical Company.



E. Observing

If you live in an area where it snows, collect some snowflakes on a piece of dark wool cloth. Before the flakes melt, examine them with a magnifying glass. The beauty you will see is well worth the effort.

Snowflakes are crystals. Although they are always ***hexagons,*** that is, they have six sides, no two snow crystals have ever been found to be exactly alike.

Crystals of snow begin to form in the same manner as a droplet of water. Molecules of water vapor become attracted to a microscopic particle in the air. If it is cold enough for ice to form, the molecules arrange themselves into crystals. Billions of water vapor molecules go to form one crystal. It should not be surprising, therefore, that no two snowflakes are alike.

PROBLEM 2: WHAT DETERMINES CLIMATES ON EARTH?

The climate of any place is determined by the types of weather it has—cool, warm, rainy, or dry. The types of weather are determined by the condition of the atmosphere. As you will recall, the temperature of the atmosphere is largely determined by the way in which the surface of the earth is heated. Not all parts of the earth are heated to the same degree by the sun. These differences affect climates.

SEASONS OF THE EARTH

Because the axis on which the earth rotates every twenty-four hours remains tilted at the same angle while the earth follows its orbit around the sun every 365 days, the earth has seasons. As you can see, on December 22, the northern end of the earth's axis is tipped away from the sun. On this day, at all points north of the equator the sun appears to be farther south than at any other time during the year, and the rays of sunlight that reach these points are more slanted at this time.

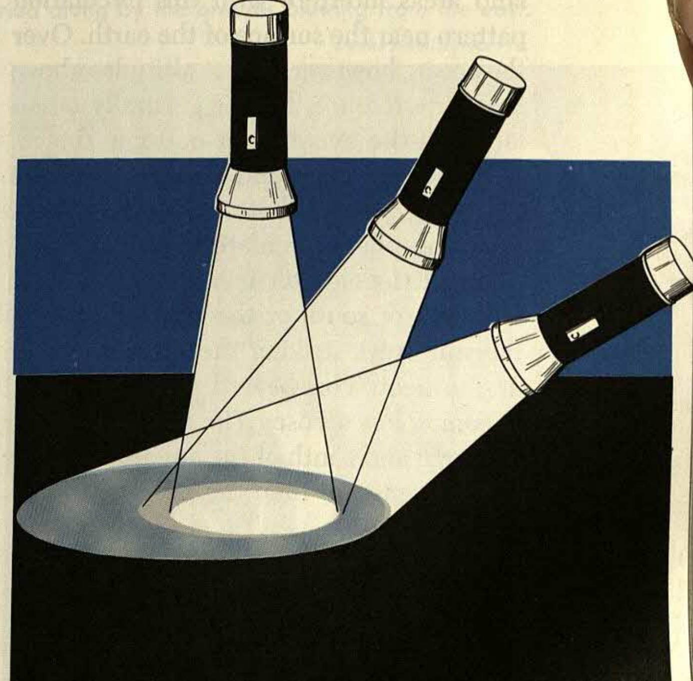
As you learned in Unit 6, page 290, when rays of the sun are slanted, they cover a larger surface of the earth and consequently do not have so great a heating effect as they do when they strike the earth directly. You can show that light rays striking an object at an angle are spread over a larger surface.

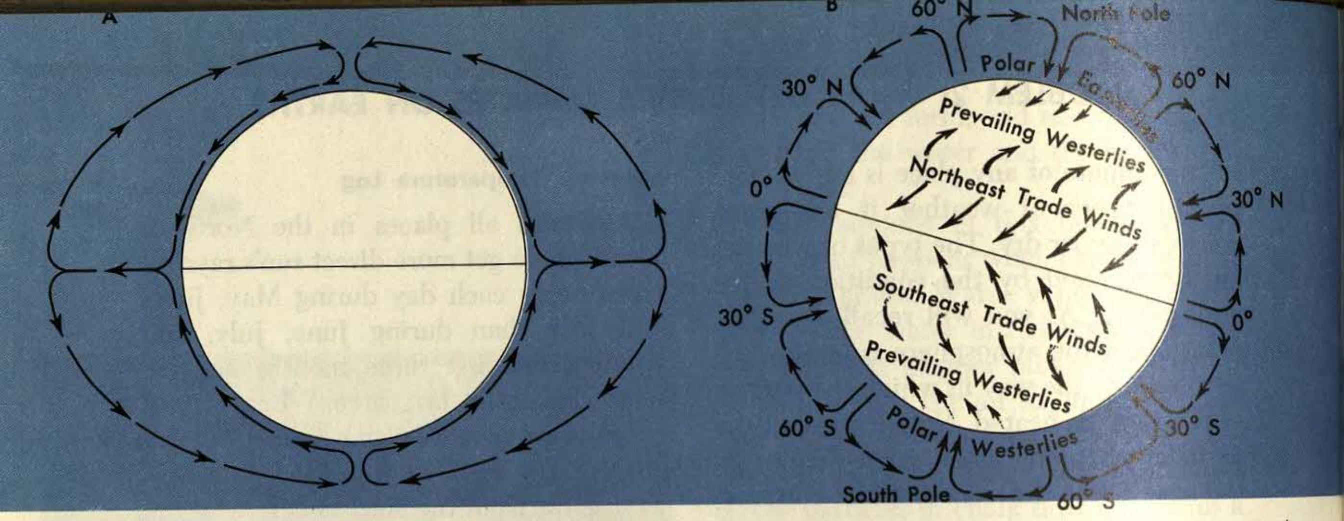
In a darkened place, hold a flashlight in three different positions—vertically, at 30°, and at 60°. Note that the farther you tip the flashlight, the larger the area that it illuminates.

Seasonal Temperature Lag

Although all places in the Northern Hemisphere get more direct sun's rays for more hours each day during May, June, and July than during June, July, and August, the first three months are not warmer than the last three. Why?

During a year, say, from January to December, the earth loses just as much heat as it gains from the sun. This is why the earth does not get warmer or colder from one year to the next. However, during the year there are times when the earth gains more heat than it loses. This happens during May, June, and July. This heat gain continues to be greater than heat loss until the latter part of August. Thus, July and August are generally the warmest months in the Northern Hemisphere. The same idea of heat lag can be used to explain why it is generally warmer in the afternoon than at noon when the most direct rays from the sun strike the earth.





Arrows in A indicate how the atmosphere over the earth would probably circulate if the earth were not tilted and did not rotate. Arrows in B show the pattern in which it actually does circulate.

CIRCULATION OF THE ATMOSPHERE

You have learned how uneven heating of the earth's atmosphere causes various types of storms. It also causes the atmosphere to circulate between the equator and the poles in a manner similar to that shown in the diagrams on this page. Although the arrows in B indicate that there is a regular flow of air in definite patterns, land areas interfere with this circulation pattern near the surface of the earth. Over the ocean, however, and at altitudes above land interference, the air generally circulates, on the average, in patterns shown.

If you refer to A and B as you read the following, you will better understand how the atmosphere circulates over the earth.

Air at the equator is heated more than air north or south of the equator because the sun's rays striking the earth there are more direct. This heated air expands and becomes less dense. The cooler, heavier air north and south of the equator is under greater pressure than the air at the equator. The heavier air, therefore, moves toward the equator to form the ***trade winds.*** These winds force up the lighter, equatorial air.

Because the air along the equator is rising, a belt of calm air, called the ***doldrums,*** is formed. After the warm air rises over the doldrums to high altitudes, it spreads out and begins to flow toward the North Pole and the South Pole.

The air continues to move poleward until it reaches latitudes about 30°N and 30°S. For reasons not completely understood, it then descends to the earth and forms another belt of calms called the ***horse latitudes.***

The descending air, when it reaches the surface of the earth, spreads out. Some of it flows toward the equator as trade winds, but the remainder flows toward the poles to form winds called the ***prevailing westerlies.*** When these winds reach latitudes about 60°N and 60°S, they are forced up by cold, heavier air moving down from the poles as ***polar easterlies.***

After this air has risen to higher altitudes, some of it continues to move toward the poles. The remainder moves toward the equator and descends to earth in the region of the horse latitudes.

Earth's Rotation and Prevailing Winds

You probably wonder why the winds of the earth generally blow from an easterly, or a westerly, direction rather than from a northerly, or a southerly, direction.

An explanation can begin with the northeast trade winds. The distance around the earth is greater at the equator than at any position north or south of it. You know that the earth rotates from west to east on its axis once every twenty-four hours. Points near the equator move faster than points north of it. The atmosphere over the horse latitudes in the Northern Hemisphere moves eastward at the same speed as the surface of the earth beneath it. When this air descends and starts flowing southward, it is not moving in an easterly direction as fast as the surface of the earth over which it is now flowing toward the equator. The southward moving air, therefore, lags behind and flows in a southwestward direction. But because the air flows *from* the northeast, the winds are called northeast trade winds. For the same reason, the trade winds in the Southern Hemisphere flow *from* the southeast and are called southeast trades.

Can the prevailing westerlies flow be explained in the same way? The surface of the earth at the horse latitudes in the Northern Hemisphere is moving east faster than the surface of the earth north of the horse latitudes. Therefore, the atmosphere over the horse latitudes is also moving faster. When air flows northward from the horse latitudes over the surface of the earth, it is, therefore, moving in an easterly direction faster than the land surface. The air, therefore, tends to flow *from* the southwest, and the winds are called westerlies. The direction in which the westerlies of the Southern Hemisphere flow can be explained in the same manner.

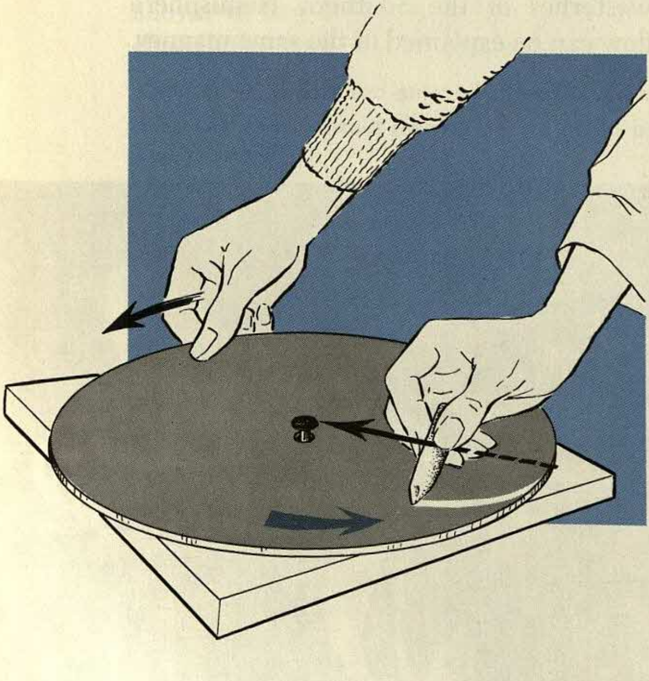
In the doldrums, left, where there is often very little wind, sailboats become becalmed. In the trade winds belt, winds are constant, and boats are carried along by the breezes blowing from the east.

Fritz Henle from Monkmeyer

Lanks from Monkmeyer

If you can get an old phonograph record, you can demonstrate how the winds of the world shift directions. A piece of cardboard cut into the shape of a record will work as well. Place the record on a board and drive a nail through the center hole to keep it in place. Let the hole represent the North Pole and the rim of the record the equator.

Turn the record slowly counterclockwise. This is the direction the earth turns when observed from above the North Pole. While you are turning the record, have someone draw a chalk line from the equator to the North Pole. The chalk line runs north from a westerly direction. Wipe off this chalk line and turn the record again. Now have someone draw a line from the North Pole to the equator. This line runs south from an easterly direction.



Average Weather in Different Belts

The doldrums are a belt of calms because there are no winds for about one-fourth of the time. When winds do blow, they are generally only light breezes which may blow from any direction. The rising warm air results in frequent thunderstorms and rain in the doldrums.

The trade winds, blowing from an easterly direction toward the equator, are rather constant over the ocean, but they are very irregular over bodies of land. Regions over which the trades blow generally have fair weather.

In the horse latitudes, light winds, which may blow from any direction, and frequent calms, occur. Clear skies, dry air, and little rainfall are typical of this belt's weather.

The westerly winds are irregular, both in strength and in the direction from which they blow. Because they blow from a westerly direction more often than from any other direction, they are called prevailing westerlies. Most of the United States is in this belt, which has many types of weather.

The weather conditions described as typical of these belts of winds and calms are average weather conditions. For most of the time, and in most places within the belt, the weather will be quite similar to that described.

OTHER CONDITIONS AFFECTING CLIMATE

There are other conditions besides the winds which might affect the climate of a place. It may be affected by its altitude, its nearness to bodies of water, or, if it is on the coast, by ocean currents.

Monkmeyer Press Photo Service

Even in winter, skiers can wear light clothing because of radiation from the sun at high altitudes.

Climate and Altitude

The atmosphere at higher altitudes lets more radiation from the sun through to the earth. It also allows the earth to lose more of its heat by radiation. Therefore, places located at high altitudes generally have cooler climates. But during the winter, when the air is cold, you will feel warm in the sun at high altitudes.

Bodies of Water

Another factor in climate is the distribution of water over the surface of the earth. Because the temperature of water changes more slowly than that of land, bodies of water such as large lakes, seas, or oceans tend to keep the temperature of nearby land areas more stable. Generally, winters and summers along the seacoast are less severe than those in the interior of a continent. Land areas near the ocean receive more precipitation than those farther inland. The farther you go into the interior of a continent, the less the rainfall and the greater the extremes of temperature you experience.

Ocean Currents

All over the world both warm and cold currents of ocean water affect the climate of land bodies along which they flow. The prevailing winds and other forces cause the water to move in regular currents.

One such warm ocean current flows north along the eastern coast of the United States and then across the Atlantic Ocean to northern Europe. It makes the climate of those areas warmer than it would otherwise be at these latitudes.

SUMMARY

The pattern of atmospheric circulation over the earth largely determines the type of climate a place has. However, its climate may be modified by altitude, mountain ranges, nearness to large bodies of water, and ocean currents.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the word that best completes the meaning of each statement.

1. Most of the United States lies in the belt of winds known as (a) prevailing westerlies (b) prevailing easterlies (c) polar easterlies (d) trade winds.

2. The belt of calm air nearest the equator is called the (a) trade winds (b) horse latitudes (c) doldrums (d) prevailing westerlies.

3. The climate of a locality is least affected by (a) circulation of the atmosphere (b) altitude (c) people living there (d) large bodies of water nearby.

4. Clear skies, dry air, and little rainfall are typical of climate (a) in the doldrums (b) in the horse latitudes (c) in areas over which the trade winds blow (d) near mountains.

5. The wind belt immediately north or south of the doldrums is called (a) the horse latitudes (b) a belt of calms (c) the trade winds (d) the prevailing westerlies.

6. Winds do not move directly northward or southward over the surface of the earth because (a) the earth rotates from west to east (b) large areas are covered by water (c) large mountain ranges interfere (d) they do not have sufficient force to cause them to blow toward the poles.

7. The sun is farthest south for all points north of the equator on (a) March 21 (b) December 22 (c) June 21 (d) September 22.

B. Estimating the Altitude of the Sun

Review the method for measuring the height of a flagpole described on page 274. You can reverse this method to measure the altitude of the noon sun at different months of the year.

Cut a piece of wood one inch thick, two inches wide, and twenty-four inches long. Nail it to another piece of wood as shown in the diagram. Make certain that it stands absolutely straight when you place it on the ground.

At noon on a clear day, set the stick on the ground so that it forms a shadow. Measure the distance, in inches, from the base of the stick to the end of the shadow on the ground.

Now take a piece of graph paper and draw the stick to scale, using one square for each inch. In a similar manner, mark the distance from the shadow to the base of the stick. Next on your paper draw a line from the end of the shadow to the top of the stick. With a protractor, measure the angle between shadow line and the line running to the top of the stick. This is the altitude of the sun.

Make these measurements once a month and compare your findings with those of other students. How could you record these measurements on a graph?

C. Making Comparisons

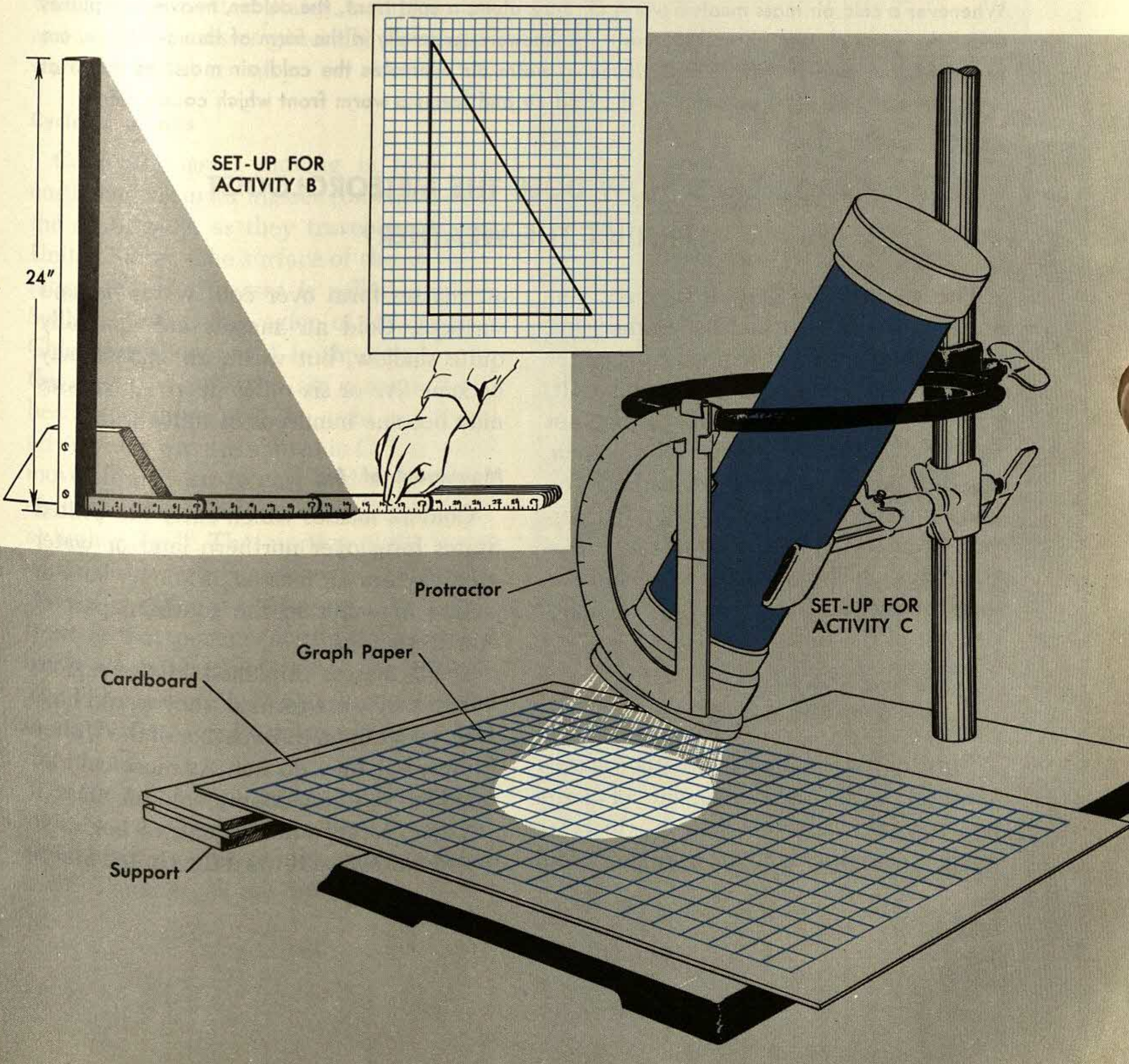
By using squared-paper (graph paper), a protractor, and the set-up on page 359, you can do an experiment to find out how the area of the lighted surface changes as the angle at which the light hits it changes. The angle that you will be measuring is the one formed between the vertical rod of the ringstand and the flashlight.

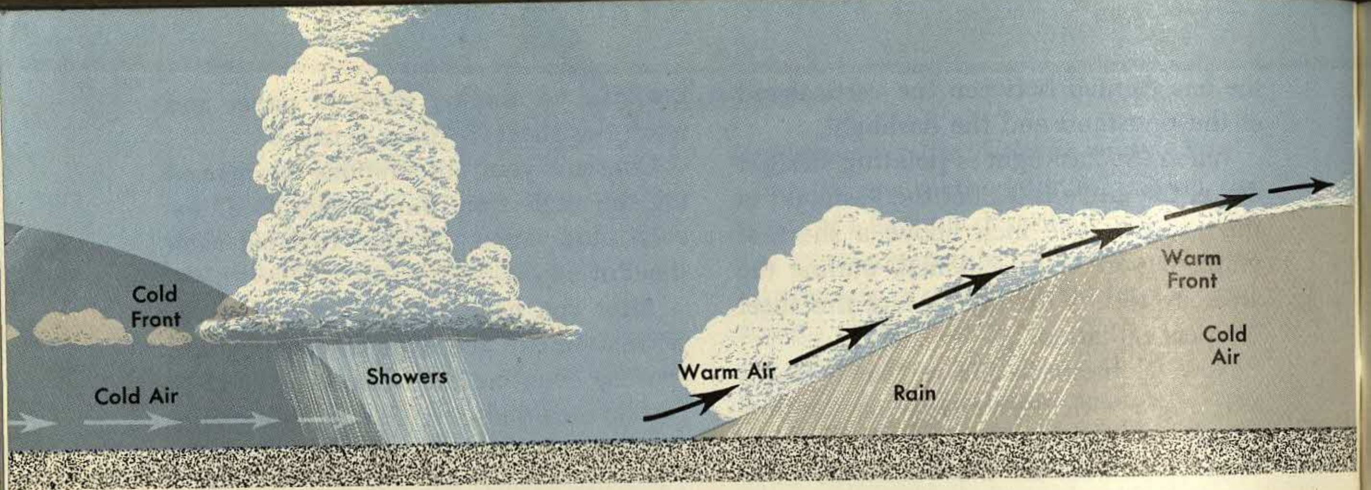
When the flashlight is pointing straight down, the angle is 0°. Set the flashlight in this position one inch above a sheet of graph paper. With a pencil, outline the area covered by the light. Mark this sheet "vertical radiation."

Now tip the flashlight so that it makes a 5° angle with the vertical bar. Outline the area on another sheet of paper and mark this sheet "5° from vertical."

Continue your observations by increasing the angle from the vertical by 5° for each observation. Be sure to label each sheet of paper.

After you have finished your observations, estimate the area of each lighted spot by counting the squares in it. Data can be recorded in a table or on a graph.





Whenever a cold air mass meets a warm air mass along a cold front, the colder, heavier air pushes under the warm air and abruptly forces it up. Showers, generally in the form of thunderstorms, are produced, as shown at left. When advancing warm air overtakes the cold air mass, as shown at right, the warm air slides up and over the cold air and forms a warm front which causes rain.

PROBLEM 3: HOW DOES THE METEOROLOGIST PREDICT THE WEATHER?

The scientist believes that, once you understand a subject such as weather, you can predict what will happen to it under different conditions. Earlier in this unit, you were told that meteorologists had not solved the weather puzzle. How, then, can they predict tomorrow's weather? You know that they can't do it with 100 percent accuracy. However, with the understandings which they do have, meteorologists' predictions are correct about eighty percent of the time.

AIR MASSES

Most of the changes in weather are associated with the movement of large bodies of air, called ***air masses,*** which are made up of either cold, or warm, air. Cold air masses form over cold water or land surfaces. Cold air masses are generally quite shallow, but warm air masses may become five or six miles deep. Air masses may become hundreds of miles wide.

Movement of Air

Cold air masses which enter the United States form over northern land or water areas. Warm air masses form over land or bodies of water in the southern part of North America.

If air masses remained in the regions where they were formed, they would have little effect upon the weather of the United States, but they do not. As more cold air is added to a developing cold air mass, it becomes larger and larger and begins to move southward toward the United States.

You can feel movement of a small cold air mass if you open the refrigerator door while you are barefooted in front of it.

Warm air masses grow over warm southern regions in the same way that cold air masses build up in the north. Warm air masses enter the United States from the south.

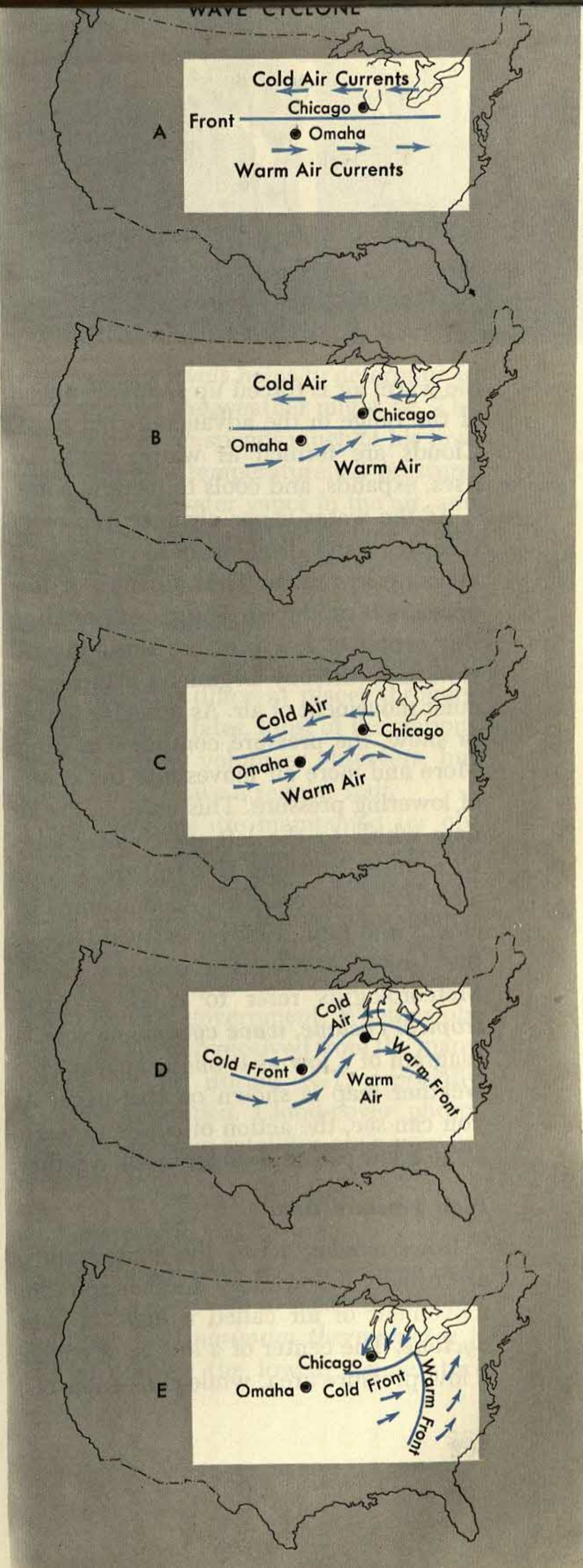
A good example of a small warm air mass is the air inside a closed car after it has been standing in the sun.

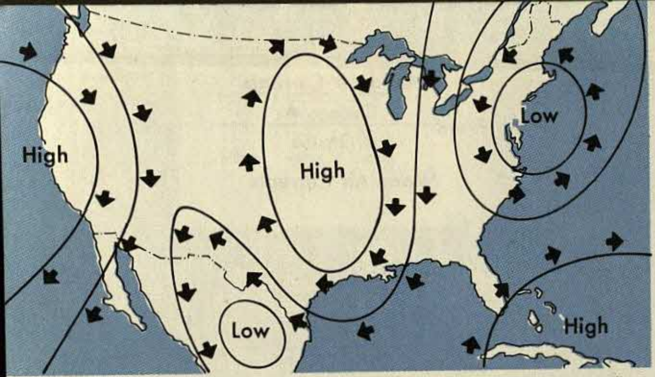
Because of the prevailing westerly winds in the United States, both the cold and warm air masses generally move eastward across the country.

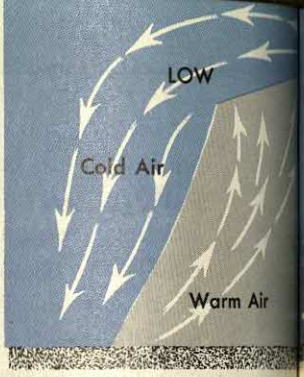
Cyclonic Storms

Cold air masses moving in from the north and warm air masses coming in from the south meet as they travel across the United States. The surface of the air separating the two masses is called a ***front.*** Such a front in the region of Omaha and Chicago is shown as A in the diagram on this page. In B, warm air currents have been turned toward the cold air mass, setting up a wave as shown in C. The wave moves from west to east under the influence of the prevailing westerlies located at higher levels. That portion of the wave where cold air replaces warm air at the ground is called a ***cold front.*** The ***warm front*** is that portion of the wave where warm air replaces cold air at the ground. The wave action in D may increase until it reaches its greatest development, as shown in E.

As the two fronts are bent into a deepening wave, clouds form where the warm air is lifted up the gently sloping warm front. Thunder clouds may form where







Map at left shows a succession of high-pressure and low-pressure areas as they move westward across the continent from the Pacific to the Atlantic. At right, a low is seen forming as two high-pressure areas of different temperature meet.

the warm air is forced up suddenly ahead of the bulge in the advancing cold front. Clouds are formed as warm, moist air rises, expands, and cools to its dew point.

As the water vapor changes into more compact water droplets, or ice crystals, it takes up less room. Thus a center of ***low pressure*** is produced. The air surrounding this center of low pressure turns inward toward it, thereby beginning a great circular movement of air. As it begins to rain or snow, the pressure continues to drop. More and more air moves into the center of lowering pressure. This wave in the air now whirls to the left, or counterclockwise, in the Northern Hemisphere, around a center of low pressure. Accompanied by clouds and rain, it moves eastward across the United States as a ***cyclonic storm.*** Meteorologists refer to it as an ***extra tropical cyclone, wave cyclone,*** or ***low.*** A diagram of a low as it might appear on a weather map is shown on this page. As you can see, the action of cold and warm air in a low causes changes in the weather.

High Pressure Area

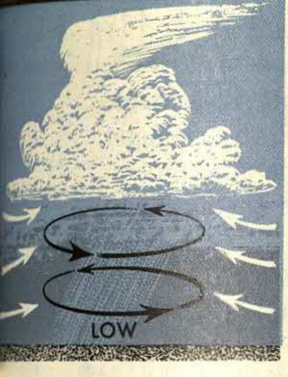
Lows moving across the United States are usually followed by another spiraling movement of air called a ***high,*** or ***anticyclone.*** The center of a low is, of course, a low-pressure area, while the center of a high is a high-pressure area. The centers of lows are characterized by ascending air currents and highs by descending air currents. Highs usually bring fair, or partly cloudy, weather.

High-Altitude Winds

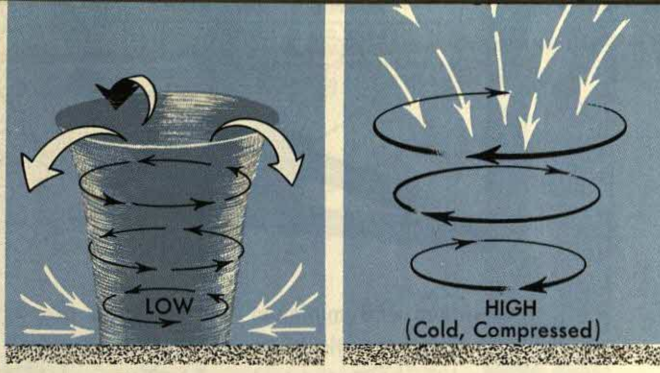
So far, only air movements and changes near the surface of the earth, as they affect the weather, have been considered. But meteorologists have discovered that what happens in the atmosphere at very high altitudes, or ***aloft,*** affects earth's weather.

The pattern and nature of winds at altitudes of 30,000 to 40,000 feet are quite different from those nearer the earth's surface. The speeds of winds aloft are very high. One such band of wind, called the ***jet stream,*** blows at speeds up to 200 miles an hour. The directional patterns of winds aloft are not the same as the earthly winds beneath them.

The movement of most storms is guided largely by winds aloft. The upper air may also develop its own cyclonic waves, which may result in clouds and rain. For a cold front to be strong, the surface winds must be blowing harder into the bulge of the front than the winds aloft. Otherwise, these high-altitude winds might move the earthly mass of warm air aside before it is lifted by cold air to form



Rapidly rising cumulonimbus cloud forms the low-pressure area shown at left. At right is a low formed over very hot places. At far right is a high-pressure area formed as air in certain areas cools, becomes compressed, and sinks back to earth.



clouds and rain. The higher winds, at other times, might reinforce the winds below and contribute to thick cloud formations and heavy precipitation. There are a number of other ways in which winds aloft may affect atmospheric conditions here on earth.

Winds Within Winds

At this point, you may be wondering what highs and lows have to do with the main wind belts which you learned about in the last problem. Take the prevailing westerlies as an example. Think of them as a large river such as the Mississippi. As the river flows slowly toward the Gulf of Mexico, several things may be happening in it at different places. At some places, there may be whirlpools where the water is flowing in a circular movement. At other places, there may be cross currents. This also happens in the river of air making up the westerlies.

WEATHER INFORMATION

Because our weather changes may originate at different levels in the atmosphere, weather observers carefully study the atmosphere from the earth up as high as they can make observations. A knowledge of the changes that occur from day to day at the various levels helps to determine in advance what the weather might be. The weather observer spends much of his time determining air temperature, air pressure, the amount of water vapor in the air, and the direction and speed of air flow at different altitudes.

Sources of Information

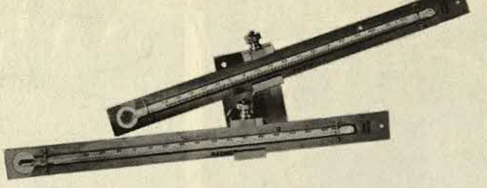
Weather observing stations are located in thousands of different places throughout the United States. Most of the stations are operated by volunteer observers, but more than 300 have a regular staff.

Weather ships are maintained for observing atmospheric conditions in the Atlantic and Pacific oceans. Weather airplanes are used to observe atmospheric conditions at high altitudes. Arctic weather observing stations are maintained by the Federal government. Weather observations are also received from the many stations set up during IGY, especially those in Antarctica. Cloud-cover photographs taken from satellites are a new information source.

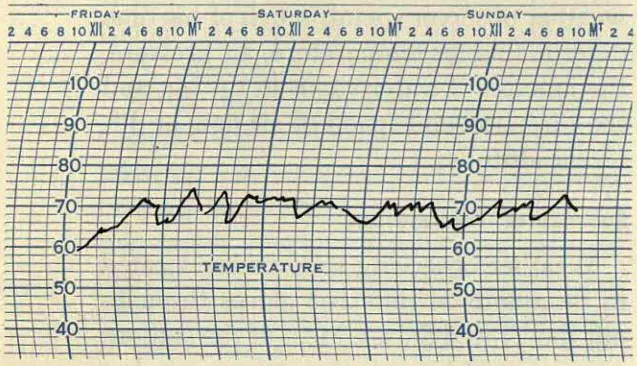
Air Temperature

Several kinds of thermometers are used by weather observers to measure air temperatures. The ***minimum thermometer*** is used to register the lowest temperature

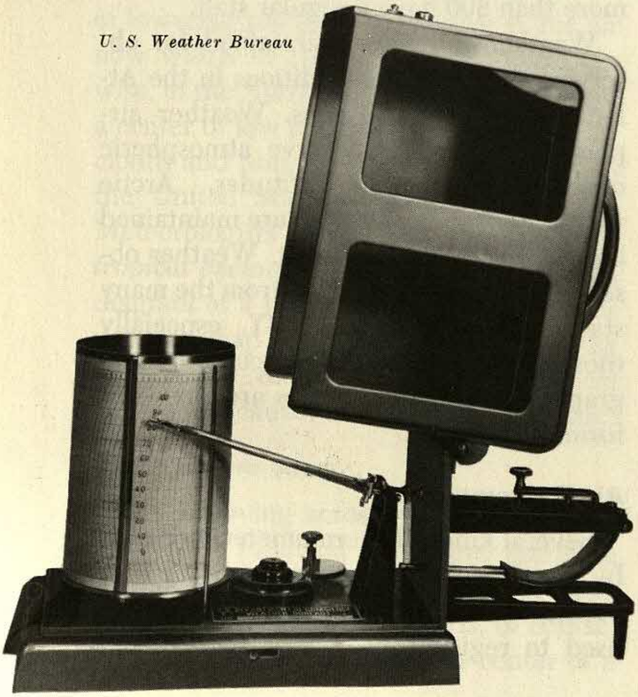
Friez Instrument Div.—Bendix



Maximum and minimum thermometers are at top. Below is a thermograph and thermograph paper on which is inked a complete record of temperature changes in a sixty-hour period.



U. S. Weather Bureau



during any period of time. It is made so that the liquid in the thermometer forces a marker down as the air temperature decreases. The marker then remains at its lowest position.

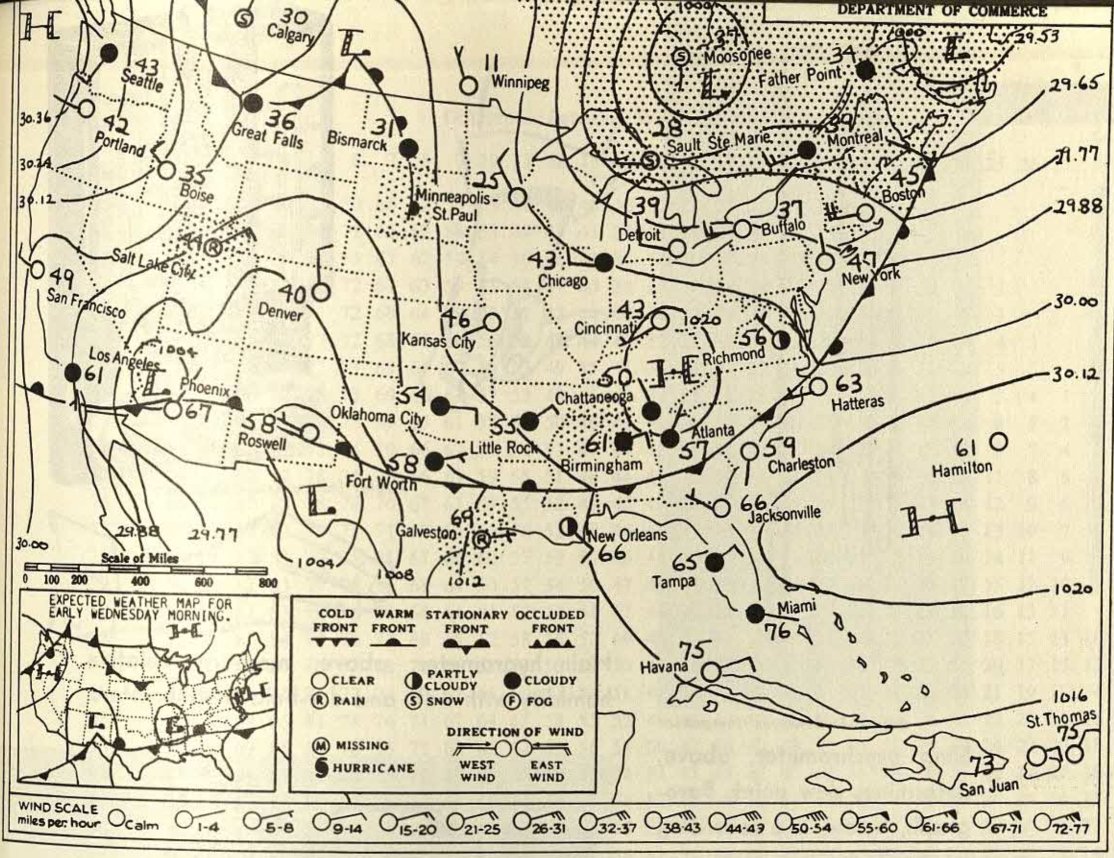
The ***maximum thermometer*** is used to record the highest air temperature for a certain period of time. In this thermometer, as the liquid rises with higher temperatures, a marker is pushed along with the liquid and remains at its highest position. The marker is reset with a small magnet.

In measuring air temperature, the thermometer should be kept out of the direct rays of the sun. Here is something you can do to see why this is important. On a clear day, hang two thermometers where the sun is shining. Arrange a hood over one thermometer to cut out the sun's rays. Compare readings on the two thermometers. The shaded one is recording air temperature. What temperature is the other one recording?

Some weather observers take readings once each hour or so with an ***alcohol,*** or ***mercury, thermometer.*** If a continuous record of air temperature is desired, the ***thermograph*** can be used. This instrument, shown on this page, keeps a complete record of daily temperature changes.

Atmospheric Pressure

Weather observers use the ***mercury barometer*** to obtain the most accurate measurements of atmospheric pressure. A glass tube closed at one end is filled with mercury. It is then placed in a container of



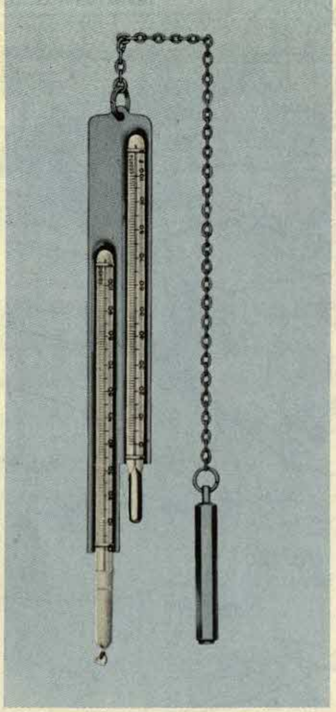
U. S. Weather Bureau—N. Y.

On the weather map of mid-continental United States, above, solid lines called isobars connect places having equal atmospheric pressure. It is reported in millibars, as well as in inches of mercury. The other numbers which appear on this map indicate both temperature and rain in inches.

mercury with the closed end of the tube at the top and the open end below the level of the mercury in the glass container. The mercury in the tube falls until its weight is equal to the atmospheric pressure on the surface of the mercury in the container. The space above the mercury in the tube contains practically no air. As the atmospheric pressure increases or decreases, the height of the mercury in the tube rises or falls. Instructions for making a mercury barometer are given on pages 374–375.

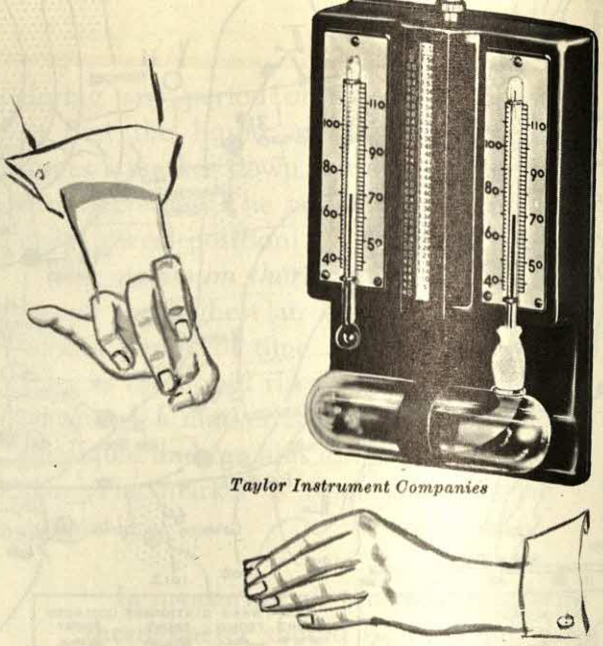
In the United States, one way of measuring atmospheric pressure is by the inches of mercury in the tube which are supported by the atmospheric pressure. In countries where the metric system of measurement is used, air pressure is measured in millimeters (mm.). When the barometer records 29.92 inches, or 760 mm., it means that the pressure of the atmosphere supports a column of mercury 29.92 inches high.

Another unit, called the ***bar***, is now used by meteorologists for measuring air



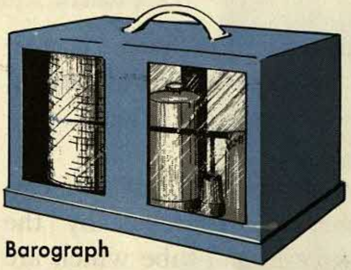
Taylor Instrument Companies

Sling psychrometer, above, determines dew point. Barograph, below, is a recording barometer.



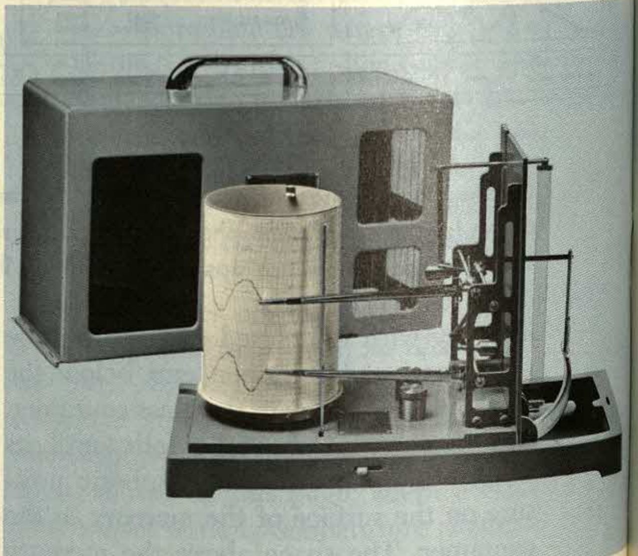
Taylor Instrument Companies

Hair hygrometer, above, measures relative humidity with wet- and dry-bulb thermometers.

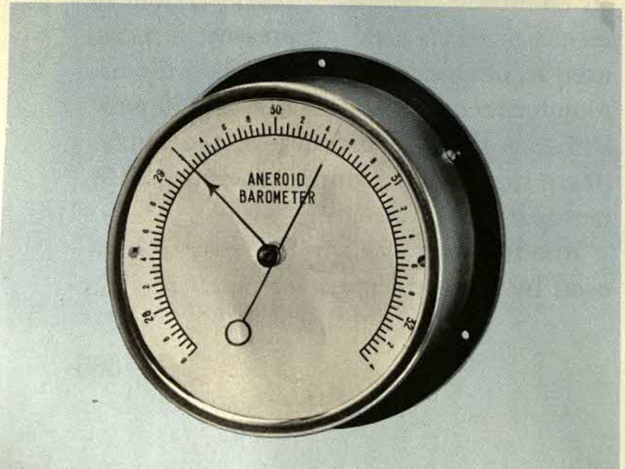


Barograph

Belfort Instrument Co.

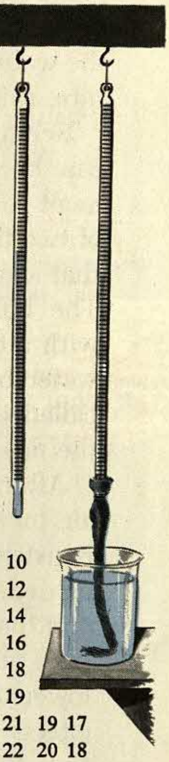


Hygrothermograph, above, records temperature and humidity. Instrument is out of its case.



Aneroid barometer, left, measures air pressure. It can also be used as an altimeter.

Dry-Bulb Reading	Difference Between Wet- and Dry-Bulb Readings																												
↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13	10	7	3						
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11	8	5	1					
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16	13	9	6	3					
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17	14	11	8	4	1				
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19	15	12	9	6	3				
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17	13	10	7	4	1			
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21	18	15	11	8	5	3			
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19	16	13	10	7	4	1		
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23	20	17	14	11	8	5	2		
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4		
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31	28	25	22	19	16	13	11	8	5		
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23	20	17	14	12	9	6		
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33	30	27	24	21	18	15	13	10	7		
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	25	22	19	16	14	11	9		
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34	31	29	26	23	20	17	15	12	10		
80	96	81	87	83	79	76	72	68	64	61	57	54	51	47	44	42	38	35	32	29	27	24	21	18	16	13	11		
82	96	92	88	84	80	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31	28	25	23	20	18	15	13	10	
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32	30	27	25	22	20	17	15	12	
86	96	92	88	85	81	77	74	70	67	63	60	57	54	51	48	45	42	39	37	34	31	29	26	24	21	19	17	14	
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	41	38	35	33	30	28	25	23	21	18	16	
90	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44	42	39	37	34	32	29	27	24	22	20	18	
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45	43	40	38	35	33	30	28	26	24	22	19	
94	96	93	89	86	82	79	75	72	69	66	63	60	57	54	52	49	46	44	41	39	36	34	32	29	27	25	23	21	19	17
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40	37	35	33	31	29	26	24	22	20	18
98	96	93	89	86	83	79	76	73	70	67	64	61	59	56	53	51	48	46	43	41	39	36	34	32	30	28	26	24	22	20
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49	47	44	42	40	37	35	33	31	29	27	25	23	21



pressure. Because the bar is a unit of pressure rather than a unit of length, it is more suitable for measuring air pressure. The United States Weather Bureau measures atmospheric pressure in ***millibars.*** A millibar is 1/1,000 of a bar, and 1,050 millibars equal thirty-one inches of mercury. Weather maps show the pressure in millibars.

The ***barograph,*** used by the weather observer to get a continuous record of air pressure, operates in much the same way as the thermograph. A pen attached to the end of a metal arm records the pressure on a revolving chart. The metal arm is attached to an ***aneroid barometer*** so that the arm moves up and down as the air pressure changes.

Water Vapor in the Air

Both the actual amount of water vapor in the air and the amount of water vapor which the air can hold are used for describing the ***humidity*** of the air. ***Absolute humidity,*** the amount of water vapor in a sample of air at any one time, is expressed in grams of water vapor per cubic meter of air. ***Relative humidity*** is the amount of water vapor the air actually contains, as compared with the total amount it could hold at any one temperature. Relative humidity is expressed in percentages. When the air is holding all the water vapor it can at a given temperature, it is ***saturated.***

Relative humidity, as well as dew point, can be determined by using an instrument called a ***psychrometer.*** This consists of two thermometers mounted on a frame that can be whirled rapidly in the air. The bulb of one thermometer, covered with a thin piece of cloth, is dipped into water before it is used and is, therefore, called the ***wet bulb.*** The other is called the ***dry bulb.***

After the psychrometer is whirled in the air for several minutes, the temperature registered by each thermometer is recorded. The dry-bulb thermometer registers the temperature of the air. The wet-bulb thermometer usually registers a lower temperature because of the cooling effects of water evaporating from its surface. The less water vapor in the air, the more rapidly the water evaporates, and the lower is the temperature recorded by the wet-bulb thermometer. The difference between the temperature recorded by the wet- and dry-bulb thermometers depends upon the amount of water vapor in the air. After the difference is obtained, both the relative humidity and the dew point can be read from specially prepared Psychrometric Tables. See page 375 for instructions for making a psychrometer.

The weather instrument below is a cup anemometer, which measures the velocity of the wind. A dial indicates the speed of the cups' revolution around the vertical shaft.

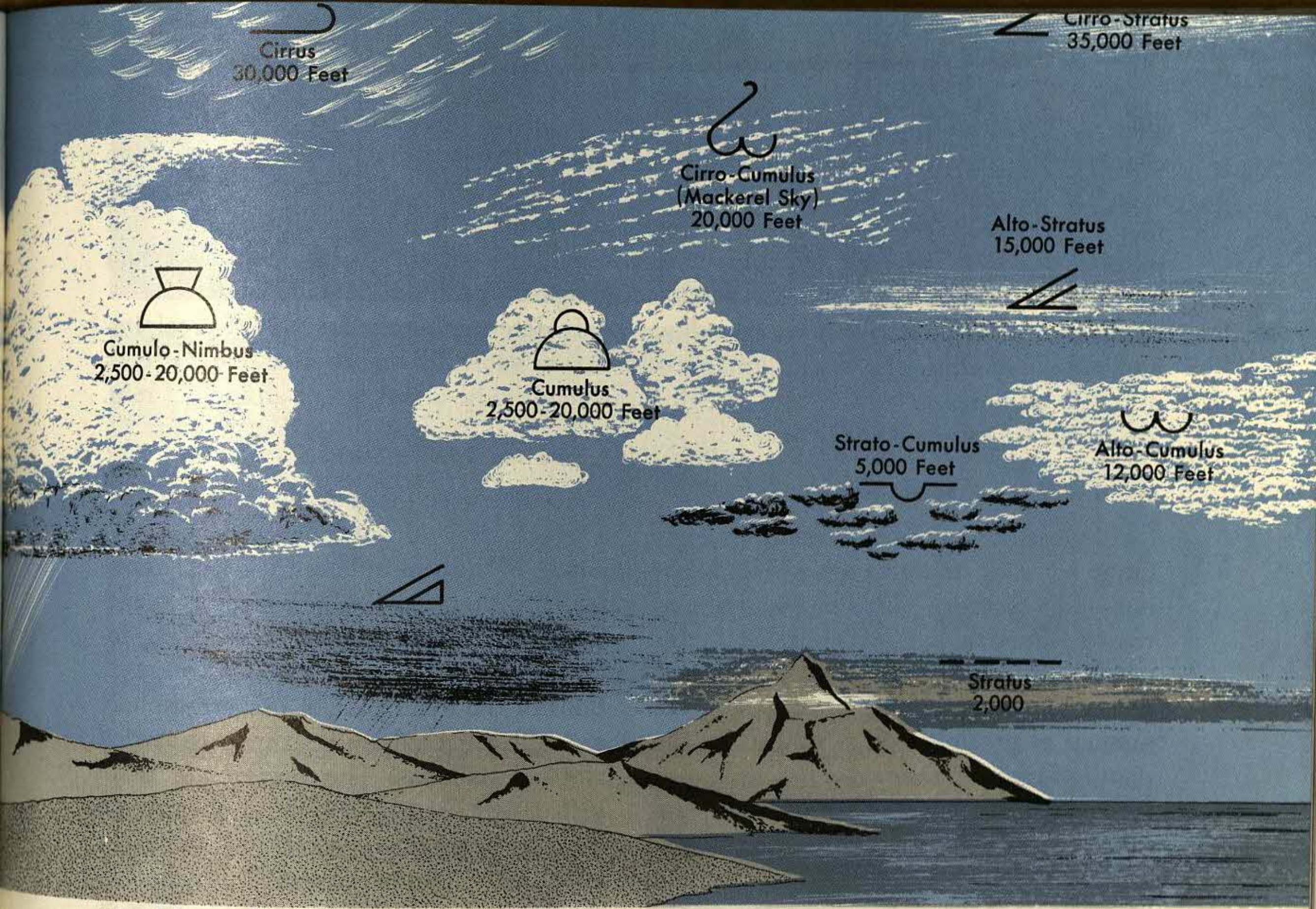
U. S. Coast Guard

Why are the wet- and dry-bulb thermometers whirled in the air? Here is an experiment you can do to help you answer the question. Use two sets of wet- and dry-bulb thermometers. Hang one set in the air, but do not disturb the air around it. Fan the other set vigorously for at least five minutes. Compare the readings of the two sets of thermometers. Why does moving the air with a fan cause water to evaporate faster from the wet-bulb thermometer? Why must wet- and dry-bulb thermometers in each set be handled alike?

To keep a continuing record of relative humidity, weather observers use the ***hygrograph.*** It operates like the thermograph and the barograph. The recording arm of the hygrograph is attached to a hair. Since changes in the humidity lengthen or shorten hair, the arm moves up and down and the pen records the changes on a chart. See page 366. A diagram for making a ***hair hygrometer*** is on page 376.

Recording Air Movements

The weather observer keeps accurate records of the speed of the wind and the direction from which it blows. ***Wind vanes***



Clouds have been classified into ten different types, according to appearance and atmospheric conditions. Note the altitudes at which different cloud types, identified by symbols, form.

are used to determine the direction of the wind. *Anemometers* are used to measure the speed of the wind. One type consists of cups mounted on an axle which turns with the wind. Speed is indicated on a speedometer.

In order to get accurate measurements of the direction and speed of wind, wind vane and anemometer must be located where there are no obstructions. Instructions for making an anemometer are on page 375.

Winds have been classified in terms of their speed. The Beaufort Wind Scale at the bottom of the weather map on page 365 is used by observers to describe winds in their weather reports.

Cloud Observations

Clouds are an indication of the condition of the atmosphere at various levels above the surface of the earth. They are formed when the air temperature becomes low enough to cause the water vapor in the air to form tiny water droplets or ice crystals. See page 344.

Clouds have been classified into ten different groups which are based on appearance and the atmospheric conditions. The ***cirrus, cirro-cumulus,*** and ***cirro-stratus*** are classified as ***high clouds*** because of the height at which they are found. The ***middle clouds*** are the ***alto-cumulus*** and ***alto-stratus. Low clouds*** are the ***strato-cumulus, stratus, nimbo-stratus, cumulus,*** and ***cumulo-nimbus.*** The cloud formations and the altitudes at which they usually are found are shown on page 369.

Measurement of Precipitation

All weather observers measure precipitation by using a rain gauge and by keeping daily records. The simplest type of rain gauge is a pan with straight sides perpendicular to the bottom. The pan is placed in the open and, after a rain, the amount of precipitation is gauged by the depth of water in the pan.

Weather observers use a standard rain gauge, as shown below, with an opening in the top exactly eight inches across. The water which enters the top part of the rain gauge runs into a long tube, where it can be measured. Because the diameter of the measuring tube is somewhat smaller than the diameter of the top of the rain gauge, each inch of water in the tube represents only ⅒ of an inch of actual rainfall. Instructions for making a rain gauge are given on page 376.

In determining the amount of precipitation as snowfall, one inch of snow is considered to be about ⅒ of an inch of rain.

Standard eight-inch rain gauge can handle up to twenty-three inches of precipitation.

Belfort Instrument Co.

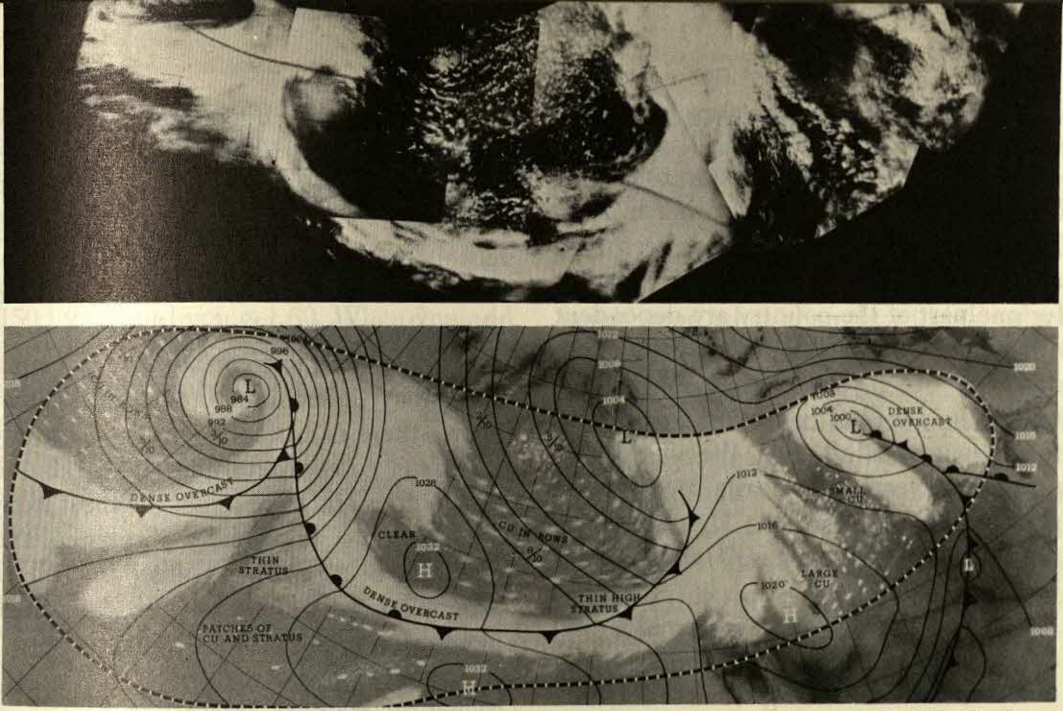
Above the Earth's Surface

Rockets have made it possible to obtain a great deal of information about the nature of the atmosphere from high above the earth to outer space. Instruments carried by satellites supply additional information. However, day-to-day observations of the main part of our atmosphere are still collected by instruments carried aloft in balloons. The ***radiosonde*** is an instrument used by a ground observer to measure atmospheric conditions at various altitudes. This instrument is attached to a helium-filled balloon which carries it as high as nineteen miles. The way this instrument is used is shown on page 371.

Small ***pilot balloons*** can be used to determine the direction and speed of the wind at different altitudes. These small rubber balloons, filled with helium, are released from the ground. Their movements in air currents are observed by means of ground instruments.

Low-altitude observations of the balloons are made with an instrument called the ***theodolite*** (thee-OD-uh-lyte).

The movement of pilot balloons at altitudes up to nineteen miles can be determined by using radar. When radar is used, a metal target is attached to the pilot balloon to reflect the radio waves.



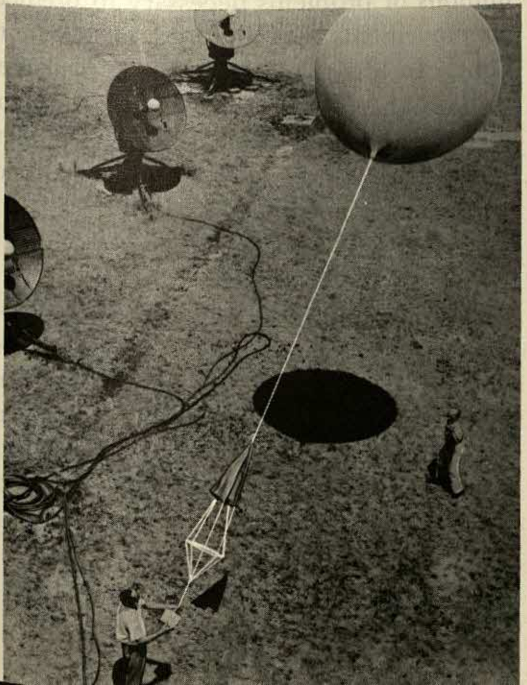
U. S. Weather Bureau

Tiros satellite produced the mosaic of weather photos at top. Below is an analysis of the photos.

Radiosonde, right, can observe atmospheric conditions up to 150,000 feet above sea level.

Weather balloon, below, tells meteorologist about speed and direction of winds aloft. Balloon in sky is observed by theodolite.

U. S. Army



U. S. Air Force

THE UNITED STATES WEATHER BUREAU

Today's weather in Chicago or Cleveland may be tomorrow's weather in New York or Philadelphia. You have seen how accurate forecasts of tomorrow's weather for one part of the country are dependent upon a knowledge of today's weather conditions in other parts of the country. The tremendous task of collecting weather information from all over the world and preparing weather forecasts for different sections of the Northern Hemisphere is now carried on by the United States Weather Bureau.

The Army, Navy, and Air Force, as well as certain commercial airlines which maintain weather-forecasting services for their own use, coöperate closely with the United States Weather Bureau in collecting and reporting weather information which is used for many purposes.

Making Forecasts

Official weather observers make their observations of atmospheric conditions at the end of every six-hour period during the day.

Daily reports from many different observers on land and at sea are sent to district forecasting centers, which are under the supervision of the Weather Bureau. In each forecast center, as soon as reports from weather-observing stations are received, the information is recorded in such a manner that the forecaster has a summary of the atmospheric conditions at each level as high as observations have been made.

The summary of atmospheric conditions near the earth is prepared in the form of a weather map such as that on page 365. From all of this information, and from all his knowledge of what might happen when a certain combination of atmospheric conditions is present, the forecaster predicts what the weather will be like in the next twenty-four hours.

Because of the great variety of conditions that determine tomorrow's atmosphere, there is not sufficient time for any forecaster to compute mathematically all possibilities and then select the most likely one. He must take many short cuts and make the best possible guess based on his experience. Sometimes he misses, although more often than not he is right.

Numerical Weather Forecasting

A computer has been built which can work millions of mathematical problems in less than an hour. The machine is being used regularly by the United States Weather Bureau. This machine makes possible ***numerical weather forecasting.*** Information from observers is fed into the computer, which has been set to solve the millions of problems necessary to predict air movements over the next twenty-four hours. In less than an hour, the machine turns out predictions which can be used to make wind charts. With these charts, the forecaster can predict tomorrow's weather with greater accuracy.

Temperature-Humidity Index

In June, 1959, the U. S. Weather Bureau began reporting a ***temperature-humidity index*** as part of its regular weather forecast. The index is a number which takes into account the atmospheric conditions which affect people's comfort.

To compute it, the dry- and wet-bulb temperatures are added. The total is multiplied by 0.4 and 15 is added to the product. For example, a dry-bulb reading of 78°F and a wet-bulb reading of 72°F, added together, gives you 150. Multiply 150 by 0.4 and you get 60. When you add 15 to 60, you get a temperature-humidity index of 75. But what does this number mean?

It has been estimated, on the basis of surveys, that some people feel uncomfortable when the index reaches 70; that more people feel uncomfortable when it is 75; and that everybody is uncomfortable when it is 80. It has also been found that work and exertion may be actually dangerous to health when the temperature-humidity index reaches 85.

SUMMARY

What tomorrow's weather will be depends upon what changes will take place in the atmosphere. In order to predict those changes, it is necessary to obtain information about atmospheric conditions throughout the world and at different altitudes as high as observations can be made. Instruments have been developed for accurate measurement and recording of atmospheric conditions. Computers give more accurate weather predictions.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The surface of air separating two air masses is known as (a) a front (b) a cyclonic storm (c) an isobar (d) a low.

2. The center of a cyclonic storm in which the air is rising is called a (a) high (b) low (c) cold front (d) warm front.

3. A barometer is used to measure (a) temperature (b) humidity (c) rainfall (d) pressure.

4. When the water vapor which the air actually contains is compared with the total amount it can hold at any one temperature, the result is known as (a) absolute humidity (b) barometric pressure (c) relative humidity (d) an isobar.

5. Masses of air over the earth are either heated or cooled by (a) the surface of the earth (b) winds aloft (c) the ionosphere (d) water vapor.

6. A cyclonic storm is a (a) high (b) westerly wind (c) cold front (d) low.

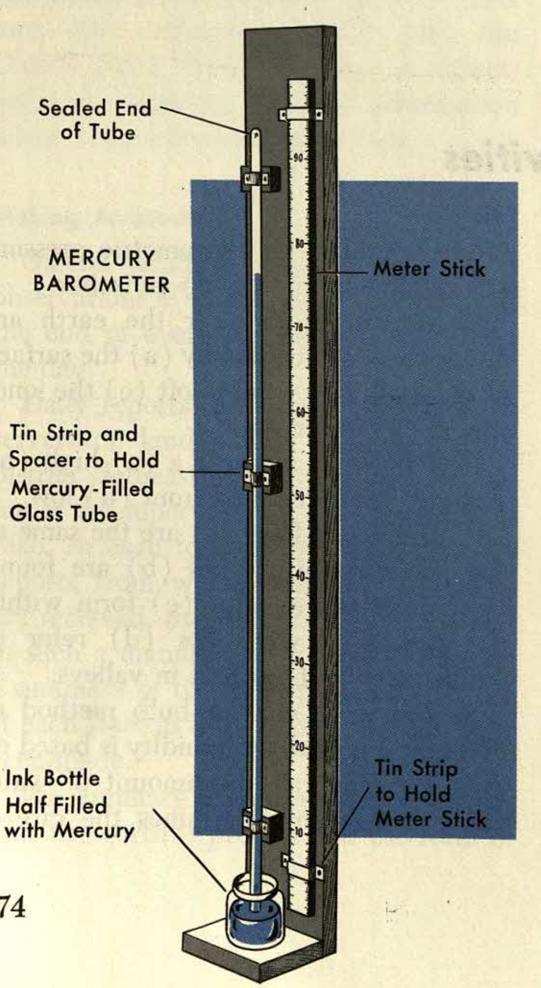
7. Highs and lows (a) are the same as the prevailing westerlies (b) are found only along the equator (c) form within the prevailing westerlies (d) refer to winds on mountains and in valleys.

8. The wet- and dry-bulb method of determining relative humidity is based on the idea that (a) the amount of water vapor in the air determines the rate of

evaporation (b) a wet-bulb thermometer will be heated less by direct rays of the sun than a dry-bulb thermometer (c) temperature has little to do with the amount of water vapor in the air (d) people are uncomfortable when the relative humidity is high.

9. In making a weather forecast, the forecaster must (a) not be influenced by his past experiences (b) be able to recall how weather in the past came about (c) get the opinion of meteorologists all over the world (d) always be sure.

10. In general, highs and lows travel across the United States from (a) south to north (b) east to west (c) north to south (d) west to east.


Sealed End of Tube
MERCURY BAROMETER
Meter Stick
90
80
70
60
50
40
30
20
10
Tin Strip and Spacer to Hold Mercury-Filled Glass Tube
Ink Bottle Half Filled with Mercury
Tin Strip to Hold Meter Stick

B. Constructing Weather Instruments

By following instructions below, you can make instruments for measuring air pressure, relative humidity, wind speed, and precipitation. Even though you may construct these instruments with great care, they may not be completely accurate. How can you check the accuracy?

1. A SIMPLE MERCURY BAROMETER. Obtain a board 1 x 4 x 42 inches, a glass tube, a meter stick, strips of tin cut from a tin can, and a balloon.

Mount the meter stick flat against the board a little to the right of center by means of two tin strips. A strip should be wound loosely around each end of the meter stick and then nailed to the board on either side of it. The strips should be attached loosely enough to permit the meter stick to be moved either up or down several inches.

Completely seal, in a flame, one end of a piece of glass tubing 36 inches long and with an outside diameter of 6 mm.

Attach a wide-mouthed ink bottle to the lower end of the board and to the left of the meter stick. After winding a strip of tin tightly around the bottle, nail the ends of the tin tightly to the board on either side of the bottle.

Fill the bottle about half full of mercury. Also fill the glass tube with mercury by means of an eye dropper. Make sure that all air bubbles are out of the mercury. Stretch a piece of thin rubber from a balloon over the open end of the tube. Hold it firmly along the sides of the tube so that the mercury will not drop out when you invert the tube.

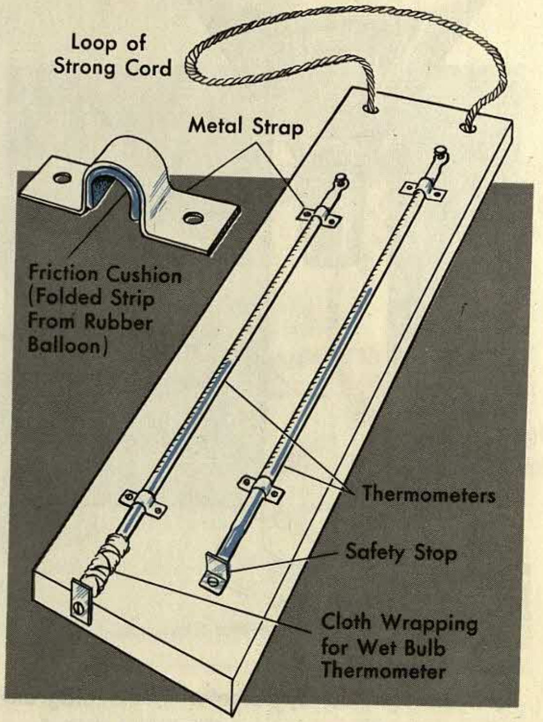
Now invert the tube and carefully insert it into the bottle in such a way that no air bubbles get into the tube. Remove the piece of rubber after the tube is in position. If air bubbles should get into the tube of mercury, repeat the process.

Use strips of tin to attach the glass tube to the board in a position parallel to that of the meter stick. Small wooden blocks will have to be put between tube and board at two places where it is attached.

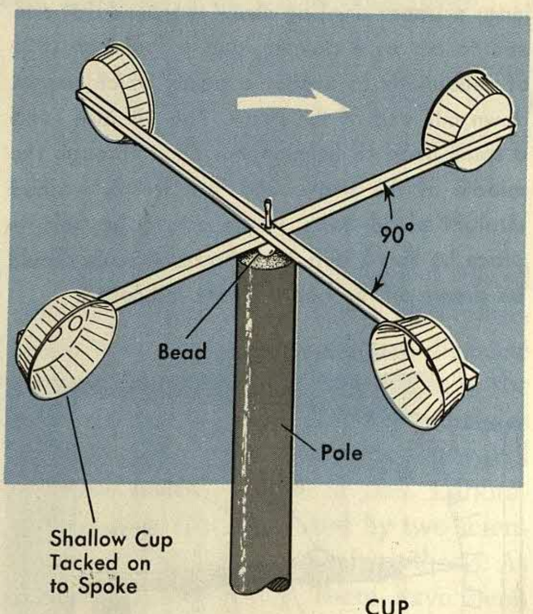
Adjust the meter stick so that the bottom of it is level with the surface of the mercury on the bottle. The height of the mercury in the tube is the measure of atmospheric pressure.

2. A Sling Psychrometer. Obtain a board 1 x 4 x 14 inches. Securely attach two thermometers in parallel positions onto the board. The thermometers should be about two inches apart, and the bulb of one thermometer should be about two inches below the bulb of the other. Wrap a thin cloth around the bulb of the lower thermometer and tie the cloth in place. Bore two holes near the upper end of the board and put through them a loop of strong cord, which the operator can hold. After wetting the cloth around the lower thermometer bulb, swing the board much as a baseball pitcher winds up before throwing the ball. Swing the board until two or more readings on the thermometers are the same. The relative humidity can be computed by using the table on page 367.

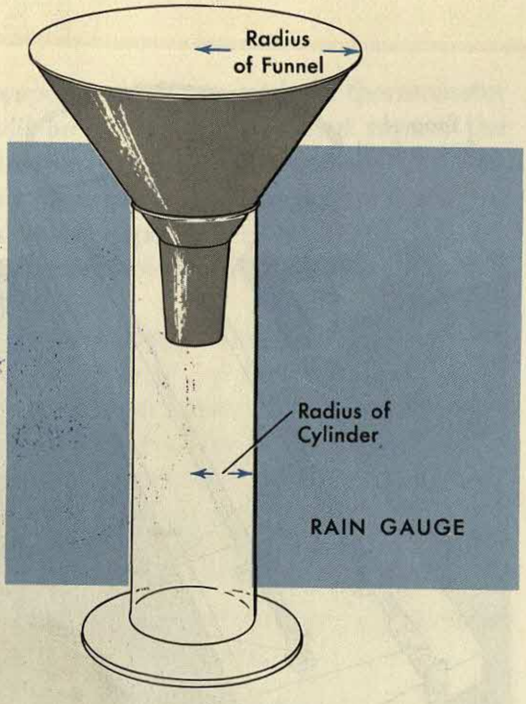
3. A Cup Anemometer. Obtain two pieces of wood ½ x ½ x 24 inches. Lay one piece of wood on top of the other so that they form four right angles. The halves of each piece of wood, from the center out, represent the spokes of a wheel. Each spoke should be exactly the


Loop of Strong Cord
Metal Strap
Friction Cushion (Folded Strip From Rubber Balloon)
Thermometers
Safety Stop
Cloth Wrapping for Wet Bulb Thermometer

SLING PSYCHROMETER

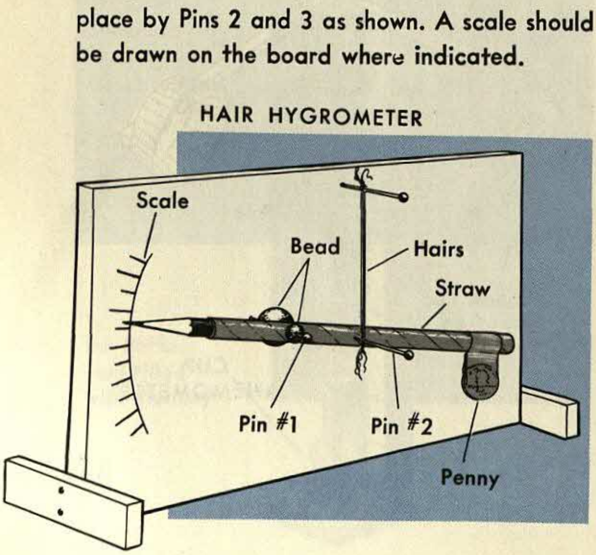


CUP ANEMOMETER



To make the hair hygrometer in the diagram below, you will need the following materials: a soft wood board about a foot wide and a foot long; a paper drinking straw sharpened at one end to act as a pointer, and a four-inch strip of cellophane to anchor a penny which weighs down one end of the straw. You will also need a small bead to help anchor Pin 1 through the middle of the straw, and four freshly washed straight blond hairs, which are to be held in place by Pins 2 and 3 as shown. A scale should be drawn on the board where indicated.

HAIR HYGROMETER



same length. Now fasten the two pieces of wood together in this position.

Bore a hole large enough for a nail at the center of each piece of wood in position corresponding to the center of a wheel.

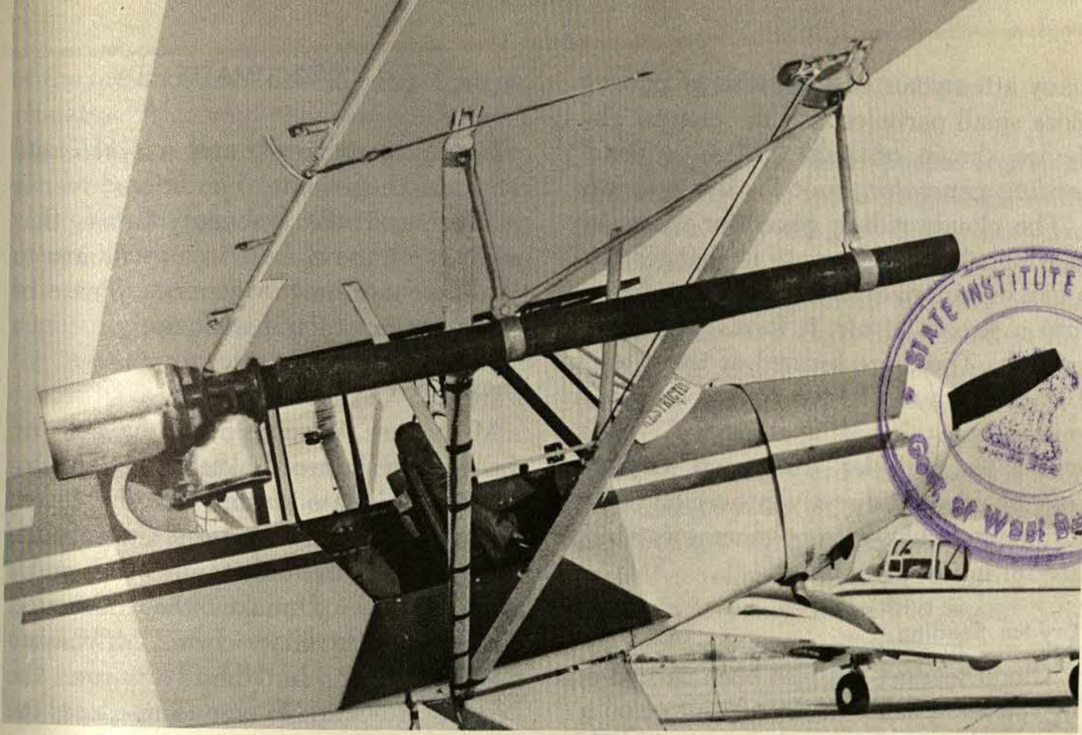
Attach a shallow paper cup to the end of each spoke in such a way that the wind will blow into each cup when the wheel is in a horizontal position.

Drive all but two inches of a finishing nail into the end of a pole. Mount the wheel in a horizontal position by passing this nail through the center hole of the wheel. It may be necessary to rub grease or soap on the end of the pole in order to make the wheel turn freely when the wind hits the cups.

4. A RAIN GAUGE. A simple one can be made by putting a funnel into a flat-bottomed glass container, such as a graduated cylinder. In order to determine what depth of water in the cylinder is equivalent to 1 inch of rainfall, divide the square of the radius of the top of the funnel by the square of the radius of the cylinder. For example, if the top of the funnel has a radius of 3 inches, and the radius of the cylinder is 1 inch, it will take 9 inches of rain in the cylinder to equal 1 inch of actual rainfall. Suppose you collected 1 inch of water in the graduated cylinder during a rainstorm. It would indicate that $1/9$ of an inch of rain had fallen.

C. Planning a Study

Plan a study to find out if the temperature-humidity index, as described on page 372, can be used to tell when most members of your class will be uncomfortable in a classroom.



STATE INSTITUTE OF EDUCATION
Govt. of West Bengal

Inst. of Atmospheric Physics, University of Arizona

Cloud-seeding generator above is strapped to plane, ready to take off on a rain-making expedition.

PROBLEM 4: CAN WEATHER AND CLIMATE BE CONTROLLED?

Man, to bring about a one-inch rain, would have to produce a tremendous amount of energy. The wind systems of the earth move the atmosphere with the energy of nearly 7,000 atomic bombs. The force which they produce in one day is greater than the electric power which could be produced in the United States in 100 years. You can see what a job it would be to control the weather of the United States on any large scale.

RAINMAKING

Because of man's great dependence on rain, he has made many attempts to produce it. Some attempts have been unscientific because they have not been based upon known facts about the formation of rain. Scientists have undertaken a few.

Cloud-Seeding Generator

One such scientific attempt is based upon the idea, or hypothesis, that sometimes clouds do not form rain because there are not enough small particles in the air. You will recall that these particles must be in the air before water vapor will condense to form drops of rain. Laboratory experiments conducted by two scientists in 1946 supported this hypothesis. As a result of their work, there have been many attempts to make it rain by putting more small particles into the clouds. The device shown on page 377 is a ***cloud-seeding generator,*** built for this purpose.

The cloud-seeding generator works by heating silver iodide until it changes into a gas, or vaporizes. When the gas is blown into a stream of air, it forms very small crystals. These are formed at the rate of 10^{15} per minute. Each crystal becomes a microscopic "freezing nucleus" upon which ice particles are grown. Crystals may be released directly into a cloud from airplanes, or blown from generators which are set up on the ground.

Dry-Ice Seeding

Cloud seeding has also been carried on by releasing flakes of dry ice into clouds. As you know, dry ice is very cold. The idea behind this operation is that if the temperature of the air in a cloud is reduced far enough, water vapor in it will condense to form rain drops.

It is extremely difficult to test the success of these methods of rain making. Because no two clouds are exactly alike, it has not been possible to set up a controlled experiment to find out how successful they have been. Before rain can be made in a cloud by either method, the conditions in the cloud have to be just right for producing rain. When silver iodide is used, the only condition lacking is something on which the water vapor can condense. Suppose a cloud were seeded by one of these methods and it rained shortly afterward. How could you be sure that the seeding was the cause and not other changes which came about naturally in the cloud?

MICROCLIMATES

Micro means small, and ***microclimate*** refers to the climate conditions over a small area. There are many things that might cause the climate in a small area to be different from the general climate of the region in which it is located.

Causes of Microclimates

Milwaukee, Wisconsin, for example, on the western shore of Lake Michigan, has a different climate from Grand Haven, Michigan, on the eastern shore, even though they are only eighty-five miles apart. The wind makes the difference. The westerlies blow from Milwaukee toward the lake, but they blow from the lake toward Grand Haven. This causes the January temperatures in Grand Haven to be 3.6°F higher than in Milwaukee. From December to February, Grand Haven gets 2.09 inches more rain. In August, the temperature in Grand Haven is 2°F lower. It snows more days in Grand Haven, and the relative humidity is five percent higher.

Even within cities such as Milwaukee and Grand Haven there will be smaller areas where the climate is different. The microclimate in the yard of one home may be quite different from the one in the yard across the street. The number of trees and their position in a yard affect the microclimate, as does the shrubbery arrangement. You could probably name many other things that would change the microclimate of a yard.

Controls of Microclimates

Heaters and air-conditioners now in houses and automobiles are good examples of the methods man uses to control microclimates. A completely air-conditioned house is one in which the microclimate can be controlled to suit man's comfort.

High-altitude flying and recent developments in space travel present situations which require radical control of microclimates. Before passenger planes can fly in the smooth air of the stratosphere, the cabins have to be pressurized. This must be done so that passengers can get the oxygen they need. To pressurize airplane cabins in the stratosphere, air from the outside can be pumped into the cabin. In space, however, there is no air outside. Astronauts have to take their air with them. Ways have been developed whereby this air can be safely used over and over. In space, astronauts also have to be protected from harmful radiations which do not reach the earth because the atmosphere screens them out. The principal problem that had to be solved before man entered space was that of providing a microclimate in which he could survive.

CHANGES IN CLIMATE

You may have heard people comment about changes in local climate. In some places they may say that their winters are colder than they used to be, or that their summers are hotter. In other places, people may say that their winters are warmer. It may be that over a period of twenty years or more, it would seem to some people that the climate has changed. Changes, however, must be observed over thousands of years before one can say that the climates of the earth are changing. Actually, reliable weather records are available for only about 100 years. Evidence of changes in climates of the past must come from less-direct sources.

Glaciers

There is convincing evidence that large glaciers have swept down from polar regions across North America on several occasions. Some have left their marks as far south as Kentucky. These movements

National Academy of Sciences—IGY photo

Scientists made a special study of glaciers in Antarctica during IGY. While on a 1,000-mile crossing, they kept records of temperature, density, and stratographic and crystalline structure in a series of shallow glaciological pits such as the one at right.

have been called the ice ages. They began about a million years ago. The last one took place about 10,000 years ago. After each glacial invasion, ice slowly melted.

It would appear that glaciers on high mountain slopes are also on the go today. To find out how much they are moving, IGY scientists have been studying them in different parts of the world. The evidences which they have obtained so far show that most of the glaciers of the world are retreating. This would indicate that the world is getting warmer. Recent temperatures in Little America, in the Antarctic, are 5°F warmer than they were fifty years ago. In Spitsbergen, islands in the Arctic Ocean, it is 10°F warmer.

Carbon Dioxide

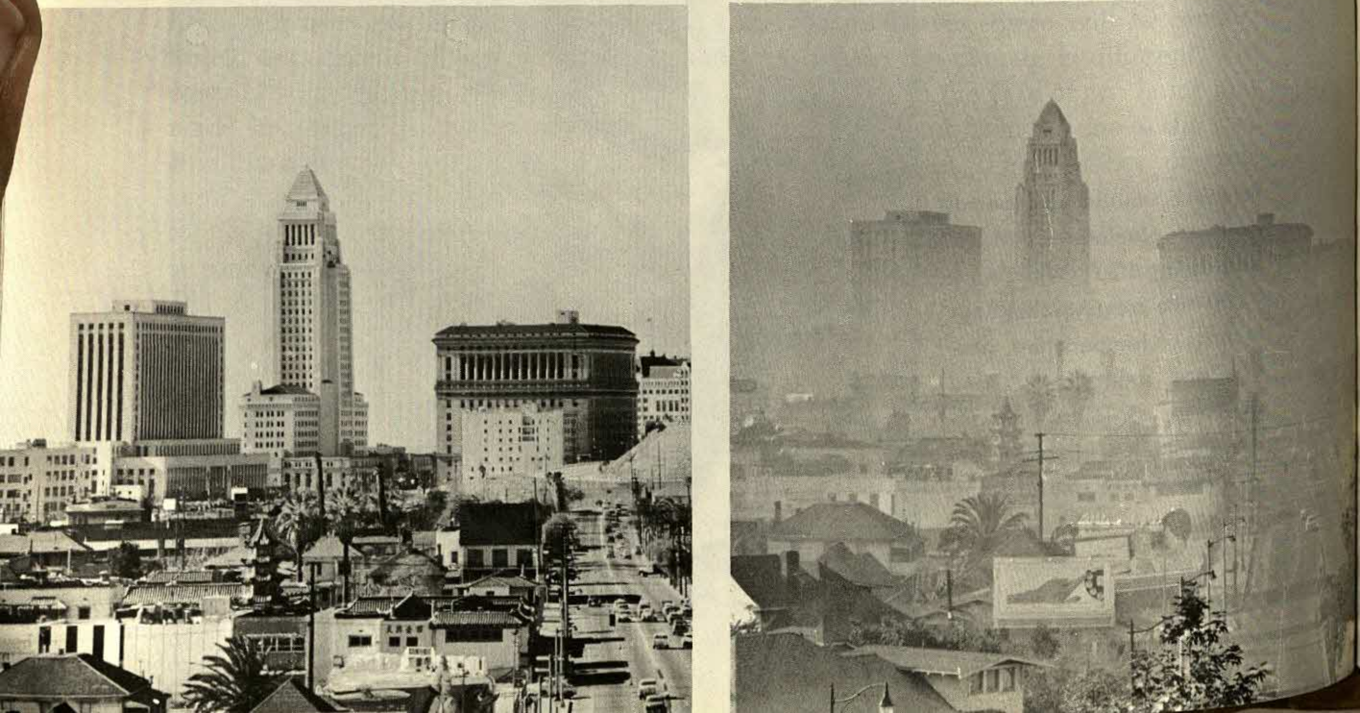
If our climate is changing, what is causing the change? The answer to this question calls for some hypothesizing because no one knows for sure. It is known that carbon dioxide in the atmosphere reemits back to the earth the heat the surfaces lose by radiation. If the carbon dioxide content—now .04 of one percent—were increased, it would tend to reduce heat loss from the earth. The climate would, therefore, become warmer. Some have speculated that, as factories and automobiles release more carbon dioxide into the earth's atmosphere, the climate will become warmer. Others believe that the additional carbon dioxide is being absorbed by ocean water, and that, therefore, it will not make much difference in the climate of the world.

Volcanic Dust

Volcanic dust in the atmosphere cuts off some solar radiation from the earth. There is evidence that the eruption of two large volcanoes, one in 1883 and the other

Temperature inversion sometimes traps layers of impure air. Under these atmospheric conditions, temperature rises with increased altitude instead of dropping. In photo at left, inversion layer is at 4,000 feet and the atmosphere is clear. At right, it is down to 1,500 feet and smog envelops city.

Air Pollution Control District—County of Los Angeles



Clouds of volcanic ash discharged into the atmosphere by erupting volcanoes reduce solar radiation.

Northwest Airlines

in 1912, was followed by cooler weather for a year or two. These weather changes did not last long enough to be considered changes in climate.

Scientists are not sure about the way in which our climate may change, if at all. There has been some speculation that man may now be living between the last and the next ice age. It is hoped that evidence collected by scientists during IGY and afterward will help to solve this puzzle.

SUMMARY

To control weather over large areas of the world would seem, at this time, to be impossible. However, man has been highly successful in his attempts to control weather on a small scale. He has developed microclimates to suit his comfort on earth. The big challenge now is to provide a suitable microclimate for man in space beyond the earth's atmosphere.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. In scientific attempts to make rain, efforts have been made to (a) supply the one condition in a cloud which will start the rain-forming process (b) control the direction in which air masses move across the country (c) get water to evaporate faster over the oceans of the world (d) obtain enough energy to change the wind systems of the world.

2. The January temperatures in Grand Haven, Michigan, are 3.6°F higher than they are in Milwaukee, Wisconsin, because (a) there are more factories in Grand Haven (b) Milwaukee is in a different wind belt (c) winds blow across Lake Michigan toward Grand Haven (d) winds blow from Lake Michigan toward Milwaukee.

3. A microclimate is made up of the types of weather found in (a) the area covered by a cold air mass (b) a small area such as a city or a yard (c) many different places within the same wind belt (d) places where there are many microörganisms.

4. One of the best evidences that climate has changed in North America is (a) the seasons (b) the shifting of winds due to rotation of the earth (c) the increased number of factories and automobiles (d) ice ages.

5. Although more carbon dioxide is being added to the atmosphere each day, some scientists believe that it will have little effect upon climate because (a) carbon dioxide has nothing to do with temperatures on the earth (b) most of it will be absorbed by the oceans (c) green plants will use it all (d) it will escape into outer space.

B. Doing Some Research

1. Make a study of tree rings from your area to find out how the weather where you live has changed from summer to summer.

2. Conduct a survey among people who have lived in your community for a long time. Question them about ways in which they think the climate has changed. Compare their opinions with climatological records for your part of the country. You can get this information by writing to the U. S. Weather Bureau, Washington, D. C.

C. Giving Reports

1. Have different members of your class find out how each of the following is affected by climate and report their findings to the class:

(a) health
(b) agricultural research
(c) livestock raising
(d) recreation
(e) lumbering
(f) aviation

2. Have different members of your class find out about each of the following and report to the class:

(a) the U. S. Weather Bureau's hurricane warning system

(b) ways in which man attempts to protect himself and property from strong winds, excessive precipitation, lightning, and temperature extremes.

Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the important ideas in this unit.

1. Why aren't the weather forecasts made by meteorologists 100 percent accurate?
2. How is the density of air affected by temperature?
3. Why does air have weight?
4. Why doesn't the moon have an atmosphere?
5. Why is it difficult to say exactly how deep the atmosphere is?
6. What are characteristics of different atmospheric layers?
7. How is the troposphere heated?
8. What is there in the atmosphere that keeps the earth from receiving direct radiation from the sun?
9. How are fog and clouds formed?
10. How are rain and snow formed?
11. What causes lightning in a thunder cloud?
12. How does the uneven heating of the earth cause circulation of the atmosphere?
13. Why do hurricanes usually get started in the tropics?
14. Why can warm air hold more water vapor than cold air?
15. Why are the sun's rays more slanted in winter than in summer?
16. What causes seasonal lag in temperature?
17. How does earth's rotation cause shifts in wind direction?
18. What kinds of weather do they generally have in each of the wind belts?
19. Why are your local weather forecasters interested in the kind of weather other parts of the country are having?
20. What is "numerical weather forecasting"?
21. What scientific facts form the basis of efforts to make it rain by using silver iodide? Dry ice?
22. Why can't the effectiveness of rainmaking methods be tested by controlled experiments?
23. In what ways can man control climate?

B. Words in Science

Write relationship between each pair below in a sentence.

1. atmospheric pressure—winds
2. gravity—atmosphere
3. cosmic rays—ionosphere
4. carbon dioxide—heat loss from the earth
5. water vapor—dew point
6. microscopic particles—rain
7. air currents—lightning
8. ultraviolet light—ozone
9. revolutions of earth—seasons
10. angle of sun's rays—circulation of atmosphere
11. ocean currents—climate
12. highs and lows—prevailing westerlies
13. water vapor—relative humidity
14. silver iodide—condensation of water
15. altitude—climate

You Can Go Further

A. By Planning Experiments

1. Plan an experiment to show that water will evaporate faster in moving air than in still air. You can do this, for example, by weighing a wet object and noting its gradual loss of weight as it dries. Fan the object as it dries. What controls are needed in this experiment?

2. Plan an experiment to determine whether open pans of water near radiators make a difference in relative humidity of classroom.

3. During dry spells in summer, people in many parts of the country sprinkle their lawns to keep the grass growing. It has been estimated that quite a lot of water in a lawn spray never gets to the lawn, but evaporates into the air. Plan an experiment to determine what percent of this water actually falls on ground around spray.

B. By Making Observations

Locate two places in your yard or in the schoolyard where it would appear that weather conditions—rainfall, temperature, relative humidity, wind speed, and so on—are different. Plan a series of weather observations in each place. Use the instruments described on pages 364–366.

Here are some suggestions for you to consider in planning this series of observations.

a. Measurements should be taken at several times each day.

b. Measurements should be taken for a period of time during different seasons to get a picture of year-round differences.

c. Daily observations should be made for at least one week, but a month would be better.

d. Maximums (highest), minimums (lowest), and averages of the different measurements should be used in your final comparisons.

C. By Reading

Bell, Corydon. *The Wonder of Snow.* New York: Hill & Wang, 1957.

Explains processes which lead up to a snowstorm, the beauty of individual snowflakes, and the effect of snow on human life.

Brindze, Ruth. *The Story of the Trade Winds.* New York: Vanguard Press, 1961.

Important material, clearly presented.

Cook, J. Gordon. *Our Astounding Atmosphere.* New York: Dial Press, 1957.

Discusses clouds, air pockets, wind currents, with emphasis on recent experiments and discoveries.

Forrester, Frank. *1001 Questions Answered About the Weather.* New York: Dodd, Mead and Company, 1957.

Discusses weather conditions around the world.

Fuerst, Robert E. *The Typhoon-Hurricane Story.* Rutland, Vt.: Charles E. Tuttle Company, 1956.

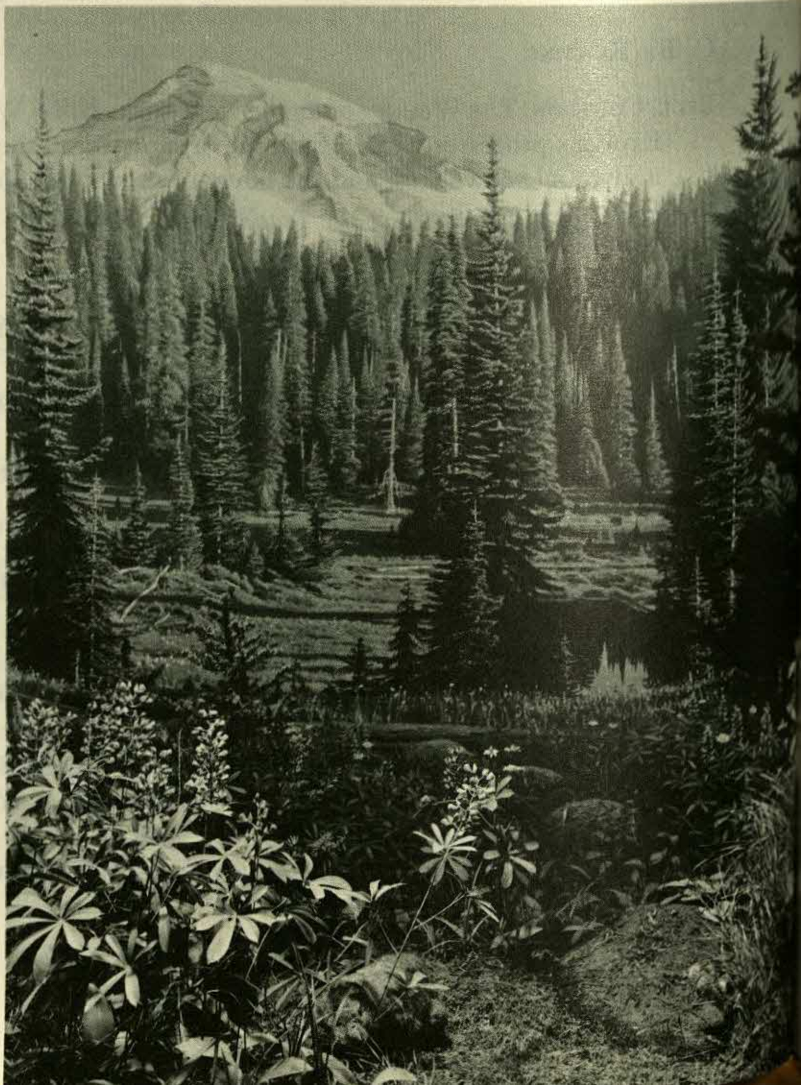
Readable account of tropical storms.

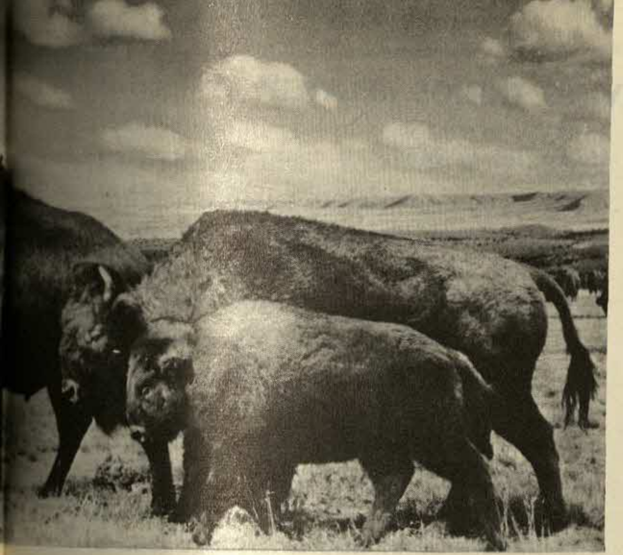
Lehr, Paul E., Burnett, R. Will and Zim, Herbert. *Weather.* New York: Simon and Schuster, 1957.

Lively survey of weather phenomena and forecasting.

Sloane, Eric. *How You Can Forecast the Weather.* New York: Fawcett Publications, Inc. (Premier Books), 1957.

A discussion of weather, enlivened by many illustrations.





American Museum of Natural History photos

UNIT 8

Living Things

Curious people have searched out a million different kinds of plants and animals, and have developed a system for giving each kind a name. They have tested various explanations of where plants and animals come from until they have found one that satisfied them. They have examined many kinds of living things until they have come up with an explanation of how plants and animals are put together and what it is that keeps them going. Patiently and accurately they have observed to find out how plants and animals can live in such a variety of environments.

The persistent efforts of these people, the ***biologists,*** have greatly increased our knowledge of living things. With this knowledge, man has been able to increase his food supply well beyond what people fifty years ago could imagine. He has become wiser in managing forest and wildlife resources. But most important of all, the knowledge gained over the years has made it possible for biologists now, and in the future, to push ahead to ever greater discoveries. Thus the science of biology grows.

PROBLEM 1: HOW ARE LIVING THINGS RELATED?

Are there living things on other planets? Who knows for sure one way or the other? Even though the most powerful telescopes will take the vision of an observer to within a quarter of a million miles of Mars, this is not close enough actually to see what's on it. However, scientists can tell how hot and cold it gets on Mars and other planets. They are also quite sure about the kinds of gases that the planets have in their atmosphere. From this evidence, they hypothesize that living things, *as man knows them on the earth,* cannot exist on other planets. Some recent evidence indicates that this hypothesis may not hold much longer.

LIVING THINGS

What is a living thing, as man knows it on earth? Take a piece of paper and try to write an answer to this question. You will find that it is not an easy thing to do because there is no single way of defining a living thing. In order to describe a living thing, you must tell what it can do and how it is related to other living things.

Living Things Move

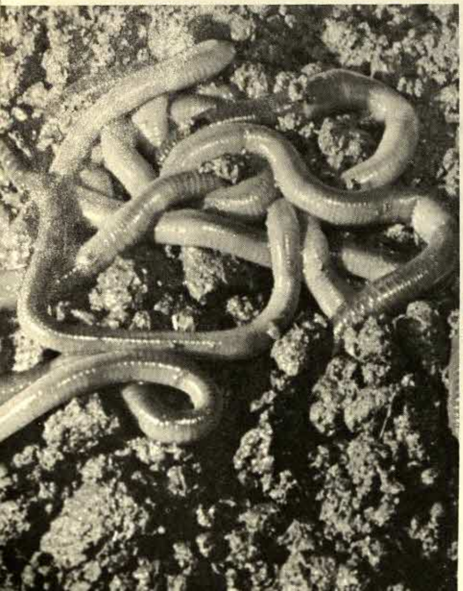
Have you ever tried to tell if something is alive? One of the first things you do is to see if it moves. If you can get close to it, you may even poke it to see what happens. If it moves, you then want to make sure that it is moving on its own.

Here is something you can do to find out how people tell if a thing is alive. Get a dead beetle or some other kind of insect. Arrange it in a small open box so that it appears to be alive. Show it to a number of different people—one at a time. Ask them to tell you if it is alive. Observe what they do. Make a list of the different things that people do to find out if something is alive.

You have learned that animals move, but what about plants? Plants also move. Living things move and they move on their own. But some other things, such as automobiles, can also move on their own. You must continue your search for other ways of describing living things.

U. S. D. A. photos

General Biological Supply House



Earthworms, being living things, respond by squirming if you touch them. Black blister beetle, above, also moves if poked. Fruit flies, right, are living things used to study heredity.

Living Things Respond

Why would you poke a bug or a worm to see if it is alive? You have learned that living things respond when you poke them. They generally respond by moving. Do you know of non-living things which also respond? There are some. For example, how does a blown-up balloon respond when you stick a pin into it? There is a difference, however, in the way a balloon and a bug respond. After the balloon responds, or bursts, it cannot respond again. This is not the case with living things. Living things are continually responding to their environment.

Collect some earthworms from soil. You can keep them in a flowerpot of soil until you are ready to use them. Conduct experiments to find out how earthworms respond to touch, light, and heat. After you think you have found out how one earthworm responds, see if others respond in the same way. You might also use such insects as small fruit flies. Frogs also make good experimental animals.

A frog, sitting motionless for long periods, often appears to be lifeless. However, a light touch will promptly bring him back to life.

Lynwood M. Chace

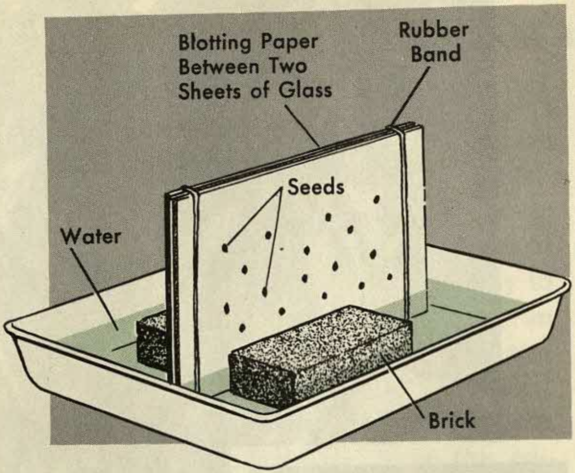
U. S. D. A.

International Harvester Co.

A corn plant anywhere from twelve to fourteen feet tall grows from a single corn kernel (inset).

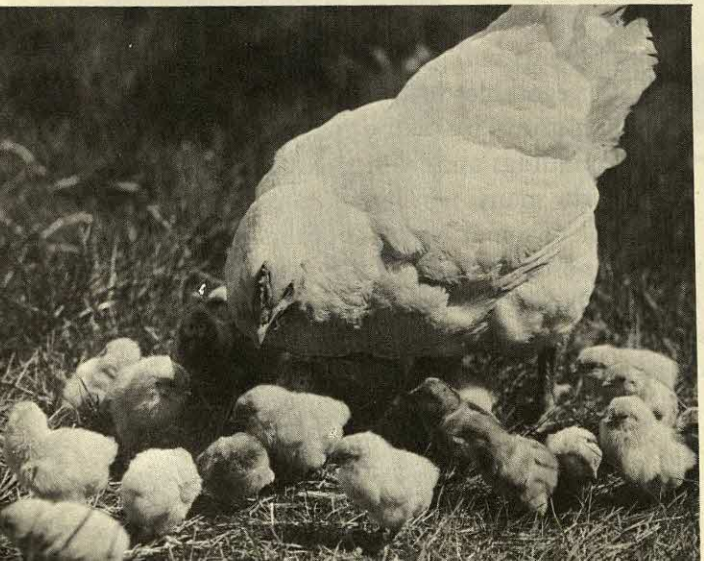
Living Things Grow

If you have ever had a garden, or worked on a farm, you are well acquainted with the growth of plants and animals. From one small package of seeds, enough plants will grow to supply a family with vegetables for the summer. A living thing grows by taking materials from its surroundings and making itself bigger. But so do many non-living things. Can you think of some? How about the growth of a raindrop or a hailstone in a cloud? Living things not only grow by getting bigger, but they change in other ways.



How fast will the roots of radishes grow? You can find out by preparing a pocket garden such as the one shown on this page.

The radish seeds are laid on blotting paper or paper towels and placed between two pieces of glass. The pieces of glass are then held together with rubber bands and placed on edge in a pan of shallow water. A brick or some such object in the pan can be used to hold your pocket garden upright.



Mother hen with flock of baby chicks is example of a living thing which reproduces itself.

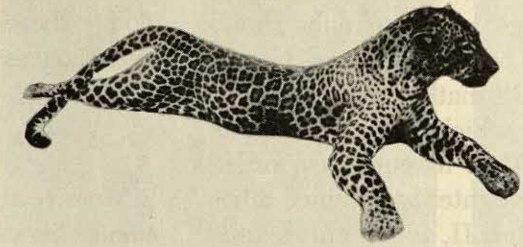
J. C. Allen & Son

Keep a record of how long it takes for each of the seeds to begin to grow. As each root appears, measure the root length of each seed every day for five days. At the end of five days, compute the percent of growth that took place each day for each seed. It will be simpler if you use the metric system of measurement. This makes it possible for you to work with decimals. For example, suppose the root from one seed grew 4.00 cms. in five days. Suppose, further, that, on the first day, it grew .8 cm. You would then divide .8 by 4.00, which would give you .20, or 20 percent. After computing the growth rate for each root, you should then average them to get the average growth rate.

Find the average daily rate of growth. If your radish root continues to grow at this rate for one month (30 days), how long would it be? If you were growing at this rate, how much taller would you be at the end of one month?

Living Things Reproduce

It is possible that a hailstone in a cloud might be broken into two smaller stones. It is possible, also, that each of the smaller stones might grow by collecting more ice from the cloud. In this way it might be possible for a non-living hailstone to reproduce, but not by itself. Something had to break the hailstone into two smaller ones. Furthermore, this is not something that you can be sure will happen to all hailstones. All living things, on the other hand, can reproduce themselves.



Monkmeyer Press Photo Service

All three animals are members of the cat family, but the one at left is known as a mountain lion, the one in the center is called a leopard, and the one at right is a Persian house cat.

THE PROBLEM OF NAMES

Living things, as man knows them, move, respond, grow, and reproduce. In these ways, all living things act alike. It is obvious, however, that they do not all look alike.

There are many different forms of life—from the simplest to the most complex. Some are so small that they weren't discovered until the microscope was invented. Others, such as the redwood trees of California, are so huge it is difficult to realize that they are living things.

Work of Biologists

Biologists, the scientists who study living things, have found about a million different ones, and they have given names to each of them. If you have ever tried to make up names for things, you can see why the task of naming one million forms of plants and animals has been a tremendous one. It has taken many hard-working biologists many years to do this, but it is a task that had to be done.

Biologists could study the different forms, but in order to tell other biologists what they had found out, they had to make certain which forms they were talking about. Of course, they could have done this by using a system which described the form each time they talked about it. You may have used this system when you wanted to talk about someone whose name you did not know. You may have referred to him as the tall boy with red hair, who is always smiling. If you and the person to whom you are talking had known that his folks had named him James, you could have used his name. There would then be less uncertainty about whom you meant.

Family Names

Do you know how your parents happened to give you your name? There is a system by which you were given your last name. It is the family name, and all members of your family have it. Some parents also have a system for giving their children first names. They may use names that have been in the family for many generations. They may use only names from the Bible, or the names of famous people. A Spanish mathematics professor had a system by which he named each of his daughters Silvia in numerical order. Thus, the first daughter was named Silvia I, the second, Silvia II, and so on. He used the same numbering system in naming his sons. In many families, no system is followed for giving children their first names.

Wherever scientists must deal with things such as plants and animals, names are necessary. If something doesn't have a name, scientists will give it one. This is what people in different parts of the world did for each of the plants and animals they knew. Generally, different naming systems were used. As a result, the same plant or animal would be known by one name in one place and by another name in another place. You can see how difficult it would be for a biologist in England to communicate with a biologist in Germany about different plants and animals. In different parts of the United States, the name ***gopher*** is applied to a small, squirrel-like animal, a snake, and a turtle. Today there is a system that is accepted by biologists in all parts of the world.

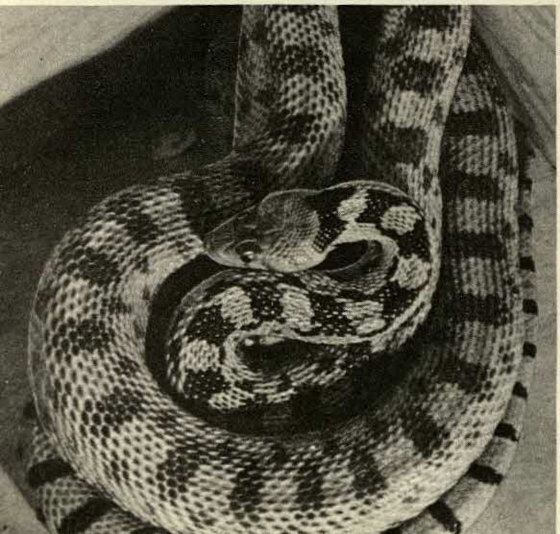
SYSTEM OF CAROLUS LINNAEUS

More than 200 years ago, ***Carolus Linnaeus*** (lih-NEE-us), a Swedish plant scientist, started the general system which is now used for naming plants and animals. Because biologists have continued to learn more about living things, the system has been revised a number of times.

The system now in use begins by classifying all living things into two kingdoms—the plant kingdom and the animal kingdom. You would probably have little difficulty in classifying the living things that you know into either the plant or animal kingdom. As you become acquainted with more living things, though, you will not find it easy to decide which is plant and which is animal. In fact, expert biologists have not always agreed on how some living things should be classified. This happens, however, in almost any system of classification.

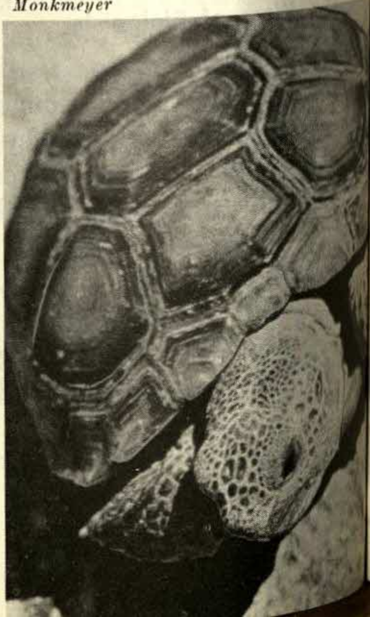
The name gopher is applied to all three animals —snake, left; small, squirrel-like creature, center, and desert tortoise at right.

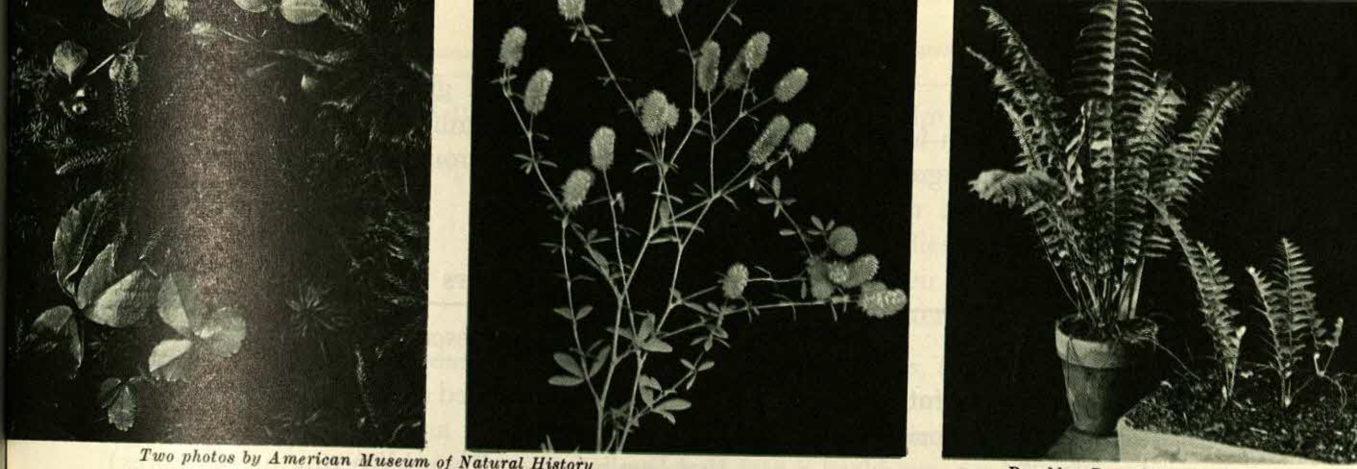
Bush from Monkmeyer



Fish and Wildlife Service—
photo by Theodore H. Scheffer

Monkmeyer





Two photos by American Museum of Natural History

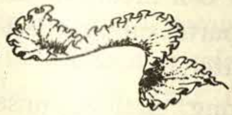
Brooklyn Botanic Garden

Spaghnum moss, left, is a Bryophyte; Rabbit Foot Clover, center, an Angiosperm. Fern is right.

The Plant Kingdom

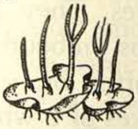
As you will see from the following table, the plant kingdom is divided into major groups. After you have read the descriptions of the different groups, list the structures that are used in telling the difference of one plant group from another plant group.

Sea Lettuce



Cup Fungi

Horned Liverwort



Boulder Fern

Pine Tree

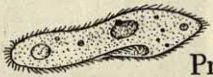
Rose

PLANT GROUPS

Group	Description
Algae	Simple green plants that live in water or in moist places. They have no roots, stems, leaves, seeds, or flowers.
Fungi	Simple non-green plants that live in water or in moist places. They have no roots, stems, leaves, seeds, or flowers.
Bryophytes	Green, moss-like plants, most of which live in moist places. They have root-like and leaf-like structures, but no seeds or flowers.
Ferns	Green plants that live on land. They have roots, stems, and leaves, but no seeds or flowers.
Gymnosperms	Green land plants, such as pine and spruce trees, that have roots, stems, leaves, and seeds, but seeds are uncovered.
Angiosperms	Green land plants that have roots, stems, leaves, seeds, but seeds are covered.

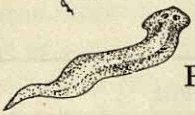
The Animal Kingdom

The animal kingdom is also divided into a number of major groups. Most of the major animal groups are shown in the table. Each group is different from each of the other groups in certain ways.

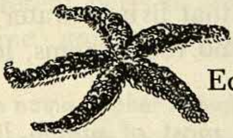

Paramecium

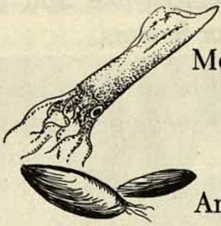
Sponge

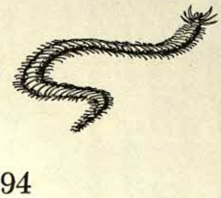
Jellyfish


Planarian

Round Worm

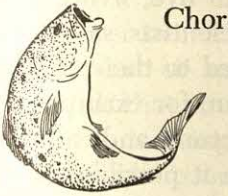

Starfish


Squid and Mussels


Sand Worm

ANIMAL GROUPS

Group	Description
Protozoa	The simplest one-celled animals that live in water.
Porifera	Simple, many-celled animals, such as sponges, that live in water. They have tiny holes (pores) through which water can enter their hollow bodies.
Coelenterata	Corals, jelly-like fishes, and sea anemones. They are hollow-bodied animals that live in water. All have a jelly-like layer between the two cell layers that make up their bodies, and all have stinging tentacles. Corals have white, or beautifully colored, hard covering.
Platyhelminthes	Flatworms. They have three cell layers in their body walls, and specialized parts, such as nerves and muscles. They live in water.
Nematoda	Roundworms. They have long, slender, unsegmented bodies and various organ systems. They are mostly parasitic, living within other animals such as dogs or cats.
Echinodermata	Starfishes and their relatives. They have spiny skins, and hard little bumps embedded in their body walls. Their bodies often branch into five parts arranged like the spokes of a wheel.
Mollusca	Oysters, clams, and snails. They have soft bodies inside of hard shells, or coverings. Squids and octopuses also belong to this group. Their bodies are covered with a material called ***chitin*** (KY-t'n).
Annelida	Earthworms, sandworms. They have ring-like sections (segments) in their body walls. They are well-developed, having hearts, blood vessels, digestive systems with many special parts, a nervous system, and other specialized systems.

Group	Description
Crayfish Arthropoda	Crayfish, shrimps, spiders, and insects. They have jointed legs and a rather hard outside covering (exoskeleton). Their bodies are divided into two or three segments. Their heads are well developed. Some live in water and some on land.
Fish  Chordata	Fish, frogs, reptiles, birds, and mammals. All the chordata have a hard, rod-like support in their backs. In most of the chordates, this support has developed into a backbone, or vertebral column. All animals with true backbones are vertebrates.

Genus and Species

The classification system which biologists have worked out has a number of sub-groups in each of the major groups previously described. Each kind of living thing is finally put into a group called the ***genus.*** Each genus group is further divided into a ***species*** group. According to the system that Linnaeus worked out, each kind of living thing is given two names. One is its genus name; the other, its species name. You may call your dog Spot, but to the biologist using this system, your dog and all other dogs are known by the name ***Canis familiaris.*** The silver maple in your backyard and all other silver maples are in the plant genus *Acer*. Their scientific name is ***Acer saccharinum.*** By using this system, biologists have named more than 850,000 different species of animals and almost 400,000 different species of plants.

Canis familiaris and *Acer saccharinum* may sound like strange names for familiar things. To give each kind of living thing a name that would be most commonly

State of Alaska—Juneau

All these animals belong to the dog family, *Canidae;* the genus, *Canis.* But coyote, below, belongs to the species *latrans,* while puppies belong to the species *familiaris.*

Marler—National Park Service

understood in different countries, Latin was commonly used; for some species, however, Greek is used.

Discuss the above names. See if you and other members of your class can figure out what each word in the name means. After you have done this, check their meanings in a good dictionary. Why do you think that such words as familiaris and saccharinum were used?

The system for classifying and naming plants and animals may seem quite involved. To any one but a trained biologist, it is. However, there is a purpose to the system. It helps to identify living things. When a biologist reads the scientific name of some plant or animal, it helps him to locate it among all other living things.

Plants and animals are classified into major groups, sub-groups, and, finally, into a genus and a species in terms of the similarities and differences. Because all dogs are similar in many ways, they are put into the genus Canis. Because all maple trees are different from dogs in many ways, they not only go into another group, but into another kingdom as well.

DIFFERENT ENVIRONMENT

Not only do living things differ in their size and shape, but in other ways. Some plants and animals, for instance, such as seaweed and fish, live their entire lives in water. Some, such as cattails and frogs, live part of their lives in water and part on land. Others, such as pine trees and deer, live entirely on land. Some land plants, such as the cactus, and animals such as a bird called the road runner, do very well in desert climates. Others can live only where there is an abundance of rain. Some plants and animals can live where it gets extremely cold in the winter, whereas others can live only in warm climates. Hence, in terms of the places in which they can live, living things are also different. Scientists say that living things are ***adapted*** to their environment. By this they mean, for example, that fish have certain structures and can do certain things that make it possible for them to live in water. And cactus plants can get along very well where it is hot and dry because of the way they are built.

Some plants become weed pests in your garden or lawn because they are better adapted to their environment than the cabbage, corn, or grass that you may be trying to grow. These pests can get along on less water and all the other things that plants need. They may also grow faster than your garden plants.

Have you ever noticed that in the woods there are only certain kinds of plants which will grow well in the shade of taller trees? Some plants will not grow well at all in the shade because they are not adapted to a shady environment. Crab grass, the weed pest in many lawns, will not grow well in shade but will take over an unshaded lawn.

Because of the different ways in which living things are adapted to their environment, plants and animals grow on almost every part of the earth. Some of the simplest plants, called ***algae*** (AL-jee), grow well in the boiling waters of hot springs. Others do well in the freezing waters of polar regions. Although living things are adapted to many different conditions on earth, there are certain things which they must have in order to grow and reproduce. These will be considered in greater detail later in this unit.

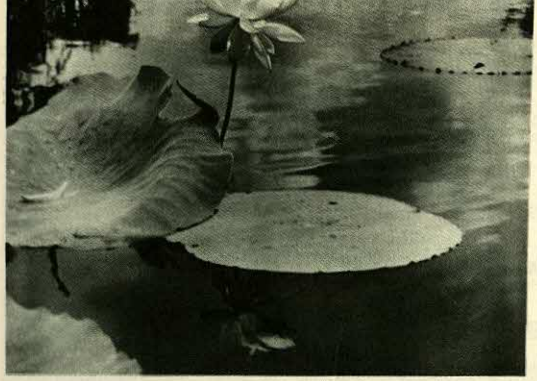
INTERDEPENDENCE OF LIVING THINGS

Have you ever seen a place where only one kind of plant or animal was living? You may think that the big tiger in the cage at the zoo is living by himself. You cannot see any plants or other animals in the cage with him. But he is not alone. Small animals and even plants find certain areas inside his body and his fur good places in which to live.

After carefully weeding your flower garden, you may think that the petunias are now living by themselves. Upon closer examination you'll find small insects on the leaves and in the soil around the roots.

It is extremely difficult to have only one kind of living thing growing in a place by itself. In laboratories, where they grow different kinds of bacteria, they do have test tubes in which only one kind of bacteria is growing. This has been made possible by the care with which laboratory workers have grown the bacteria.

Under natural conditions, different kinds of living things find it convenient to live together. The plants that grow in the shade of forest trees find that environment best suited to their needs. The fleas that grow in the fur of the tiger find that environment best for them. There are many examples of plants or animals living together in these ways. They do not live together because they like each other but because they depend upon each other.



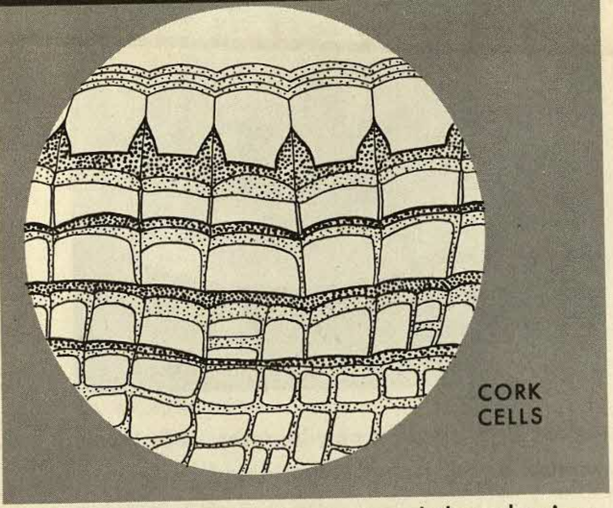
Standard Oil Co. (N. J.)

Giant lilies can grow only in water, while thorny cactus, below, thrives in dry, desert soil.

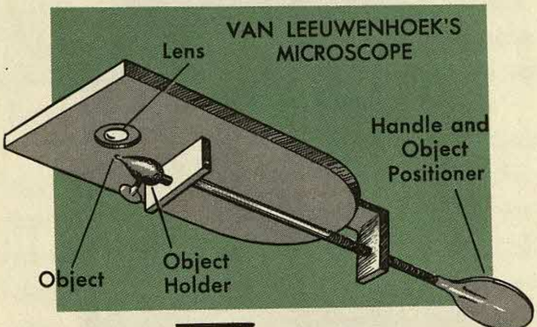
American Museum of Natural History

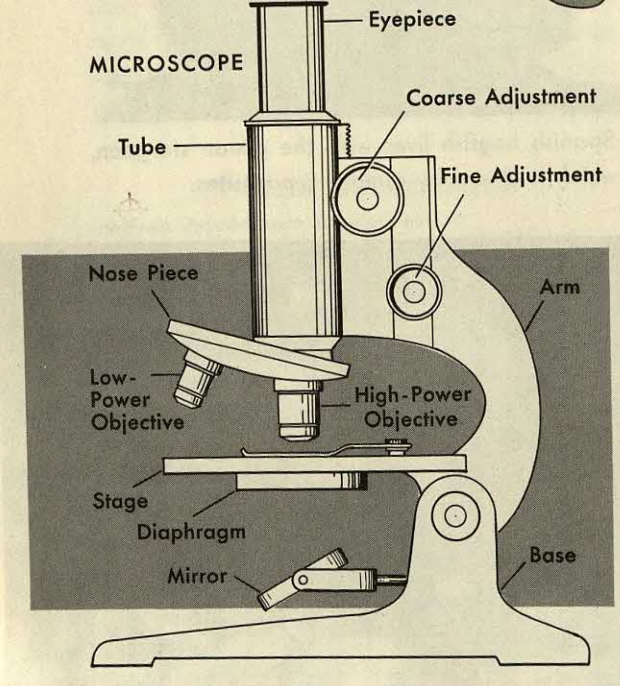
Spanish hogfish lives with the ocean sturgeon, which it cleans by removing parasites.

Conrad Limbaugh from Scientific American



Section of cork, above, viewed through microscope. Microscope below is similar to Van Leeuwenhoek's. Microscope at bottom is commonly used in classroom science projects.





ROLE OF THE MICROSCOPE

As you learned in Unit 6, the invention of the telescope opened the door to a part of the universe that had been beyond man's ability to see on his own. In a similar way, the microscope opened the door to another unseen universe. The telescope uses lenses to make faraway objects appear to come nearer and seem larger. Lenses are used in a microscope to make small objects appear larger.

In 1665, Robert Hooke, an Englishman, used one of the first microscopes to examine thin pieces of cork, which is the outer bark of the cork oak. At one time, is was part of a living thing. Hooke saw small spaces in the cork, such as those shown at left. He called them ***cells.***

A few years later, ***Anton Van Leeuwenhoek*** (LAY-vin-hook) used a microscope which he had made to examine stagnant rain water which he took from a barrel. In it he discovered many different kinds of living things. He was sure they were alive because they were moving. They were not any larger than the cells that Hooke had seen in the cork.

A picture of Leeuwenhoek's microscope is shown at left. Below it is a microscope of the type used by biology students today. Biologists find microscopes as important in their work as astronomers find telescopes in theirs.

CELLS

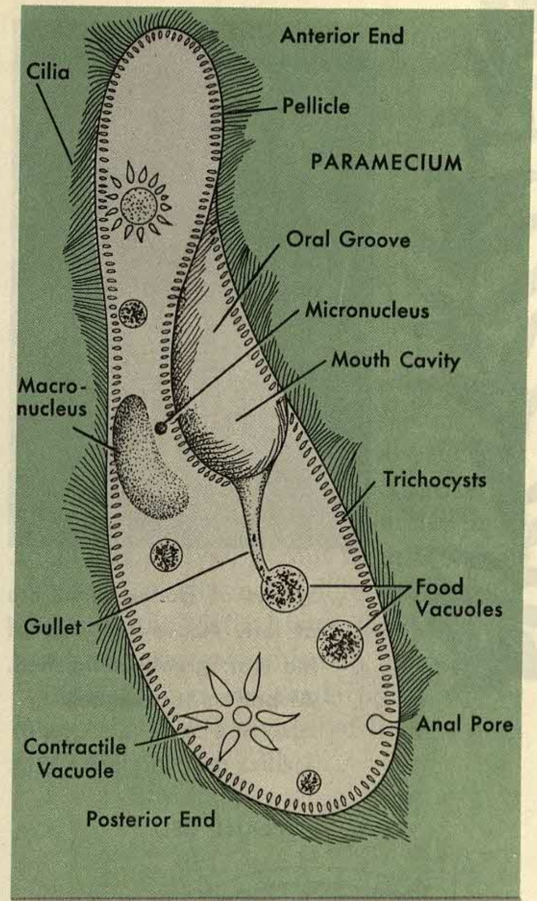
After its invention, the microscope was used widely by biologists to study plants and animals. Many other one-celled animals, similar to those Leeuwenhoek had seen, were discovered, as were a number of one-celled plants.

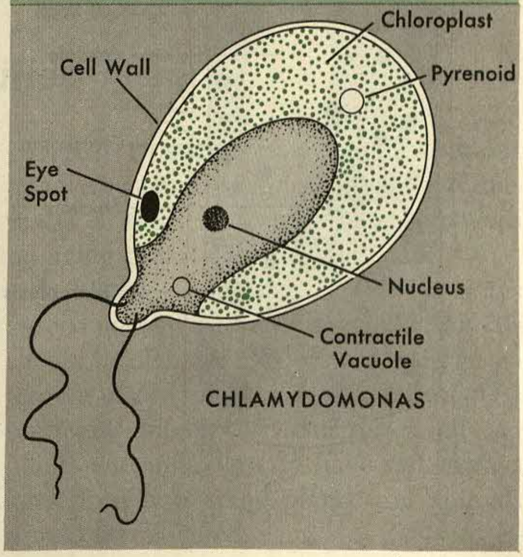
Parts of many different kinds of plants and animals were examined. Each part was found to be made up of smaller parts. In plants, many of these smaller parts looked very much like those which Hooke had found in cork. Generally, in animals they did not stand out so clearly, but they were nonetheless there. These smaller parts of plants and animals became known as cells.

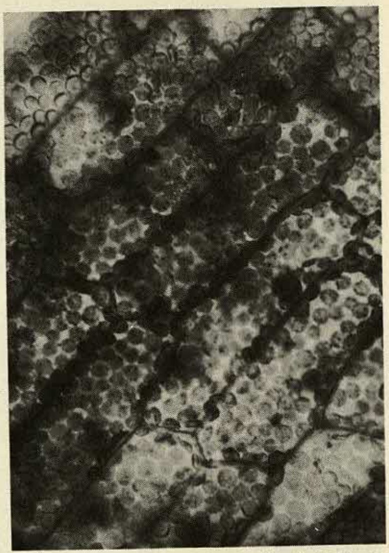
Evidence collected by the use of the microscope led to development of one of the most important ideas in biology. As you know, ideas are developed in the minds of men. Often the ideas come only after a great deal of evidence has been collected and much thinking has been done. It was not until 1839 that two noted German biologists, Matthias J. Schleiden and Theodor Schwann, formulated the cell idea into a generalization. They wrote that *all living things are made up of cells; they are either single cells or groups of many cells.*

As you will learn later in this unit, there are many different kinds of cells. In the many-celled plants and animals such as the maple tree or the dog, there are many kinds of cells. Even the one-celled plant and animal shown at right appear in many forms. All cells, however, are similar in the way in which they are put together.

The main parts of a plant cell are shown in the diagram on page 400. These are cells from the leaf of a water plant called Elodea. When viewed through a microscope, some of the parts would not be seen so clearly as you can see them in this diagram.

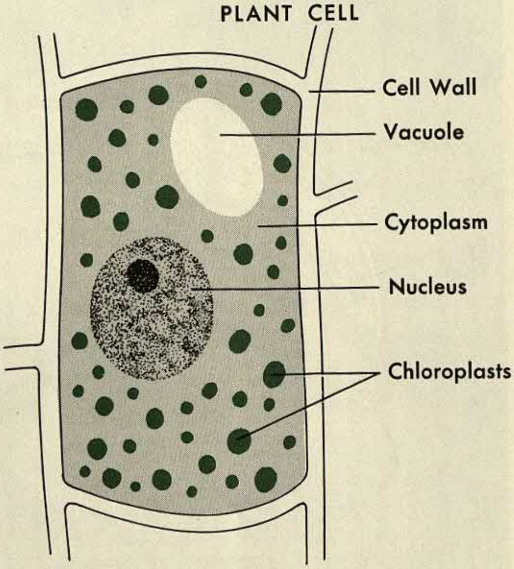






Hugh Spencer

Sprays of Elodea plant are at left. Above are cells of the leaf, greatly magnified. At bottom is plant cell.



Membranes and Walls

As you will note, each cell is surrounded by a very thin film called a cell ***membrane,*** which separates one cell from the other. In plant cells, there is a heavier layer outside the cell membrane, called the cell ***wall.*** Cell walls are what surrounded the spaces which Hooke saw in his thin slice of cork.

Cytoplasm and Chlorophyll

Inside the cell membrane is a jelly-like material called the ***cytoplasm.*** Cytoplasm is a very complex mixture of many different chemicals. When you view the cytoplasm of a cell with a microscope, it appears to be flowing in the cell like a little stream. The small dots that you see in the cytoplasm of the leaf cell are little bodies that carry the green material which is called ***chlorophyll.***

Nucleus of Cell

The nucleus is the control center and regulates everything that happens in the cell. The complex mixtures that go to make up the nucleus are called ***nucleoplasm.*** The cytoplasm and the nucleoplasm together have been called the ***protoplasm*** of a cell. Because they are so different, it is better not to use the term protoplasm when talking about either.

Vacuoles of Plant

In plant cells, there are spaces in the cytoplasm called ***vacuoles,*** each of which is surrounded by a membrane. The plant vacuole contains water with different materials dissolved in it. As you can see in the diagram, some plant cells have very large vacuoles.

Aside from certain protozoa, most animal cells do not have sharply defined vacuoles. In general, they are smaller than plant vacuoles. In the protozoa, certain vacuoles, called ***contractile*** vacuoles, have special functions. Their purpose is to get rid of excess water which accumulates in the animal as it feeds.

Functions of Cells

Biologists have found a number of kinds of materials in both the cytoplasm and the nucleoplasm. They have found out what some of these materials do, but the functions of others are still puzzles. If you go on to a study of biology, you will learn about them.

As you will find out later in this unit, cells are responsible for all things that happen in plants and animals. Living things respond and move because of activities that take place in their cells. Cells are also responsible for the growth and reproduction of living things.

SUMMARY

Living things as man knows them on the planet earth are related in many ways. They respond, move, grow, and reproduce themselves. Because of the many different kinds of living things, biologists have had to develop a system for classifying and naming each kind. This has been necessary in order to study them in a systematic way.

Some kinds of plants and animals have adaptations which permit them to live in almost all of the many different kinds of places on the earth. Living things are dependent upon each other in many ways.

Living things are made up of one or more cells. The activities of living things take place in their cells.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. All living things respond, move, reproduce, and (a) live in water (b) fly (c) grow (d) produce seed.

2. It was necessary for biologists to classify and name the million different kinds of living things so that (a) they could study them systematically (b) they would know which ones hadn't been discovered (c) each country could work out its own system for naming plants and animals (d) they could show why there were no living things on other planets.

3. Expert biologists (a) have always agreed on how certain plants and animals should be classified (b) do not need a system for classifying plants and animals (c) use many different systems for classifying plants and animals (d) have not always agreed on how some plants and animals should be classified.

4. Different kinds of living things have been given two names. One is the genus name and the other the (a) cell name (b) species name (c) scientific name (d) kingdom name.

5. Most of the scientific names of plants and animals have been taken from (a) Chinese (b) French (c) English (d) Latin.

6. A plant or animal that can live in a desert climate (a) is adapted to that environment (b) can live without any water (c) can live on the moon (d) is a one-celled plant or animal.

7. Plant and animal cells were not discovered until the invention of the (a) spectroscope (b) telescope (c) microscope (d) cystoscope.

8. All things that go on in cells are controlled by (a) vacuoles (b) the nucleus (c) the cell membrane (d) the cell wall.

9. The cytoplasm of a cell is (a) all water (b) found in the nucleus (c) the same as the cell membrane (d) a complicated mixture of many materials.

10. Single-celled plants and animals (a) depend upon other living things (b) do not reproduce (c) do not grow (d) do not need a nucleus.

B. Making Classification Systems

Have each person in your class bring in a collection of many different kinds of small objects. Put them all together on a table. Now work out a system by which you can divide the objects into different groups. Write a description of each group which you decide to use in your classification system. Make sure that you have described each group so that each object can be put into one, or the other, of the different groups.

C. Studying Plant Adaptations

1. On page 385, Unit 7, it was suggested that you locate places that have different microclimates. Make another study of these same places. Do the same kinds of plants grow in each place?

2. If there is a pond or swamp near your home or school, visit it. Note the kind of plants that are growing near the water. Then walk some distance back from the wet places and note the kinds of plants around you. Are they the same?

D. Observing Cells

If you have a microscope in your school, you can easily observe several different kinds of cells. Before you can see anything through a microscope, the material has to be so thin that light will pass through it. Here are three places where you can easily get thin material made up of cells.

There is a very thin lining of skin on the inside of your cheek. If you scrape it gently with the edge of a toothpick, you will get some of it on the toothpick. Rub this material into a drop of water on a microscope slide. A little bit of iodine in the drop of water will stain the cells so that you can see them more easily.

If you remove one of the heavier layers from an onion, you will find a very thin skin covering the inside of it. Peel this off and put a part of it on the microscope slide as you did your cheek cells.

There is also a very thin layer of cells covering the upper and lower sides of leaves. If you work carefully with a pair of forceps (tweezers), you can remove some of this layer from the lower side of a geranium leaf. Prepare the leaf cells as you did the others for examination under the microscope.

Caterpillar Tractor Co.

On large farms, beef and dairy cattle are provided with ample food to insure good growth.

PROBLEM 2: HOW ARE LIVING THINGS PROPAGATED?

The food man eats and many of the materials he uses in making his clothing come from plants and animals. At one time, man found it possible to obtain sufficient food and other materials from the plants and animals growing naturally on the earth. For many centuries, however, the natural supply of plants and animals has not been sufficient for man's needs.

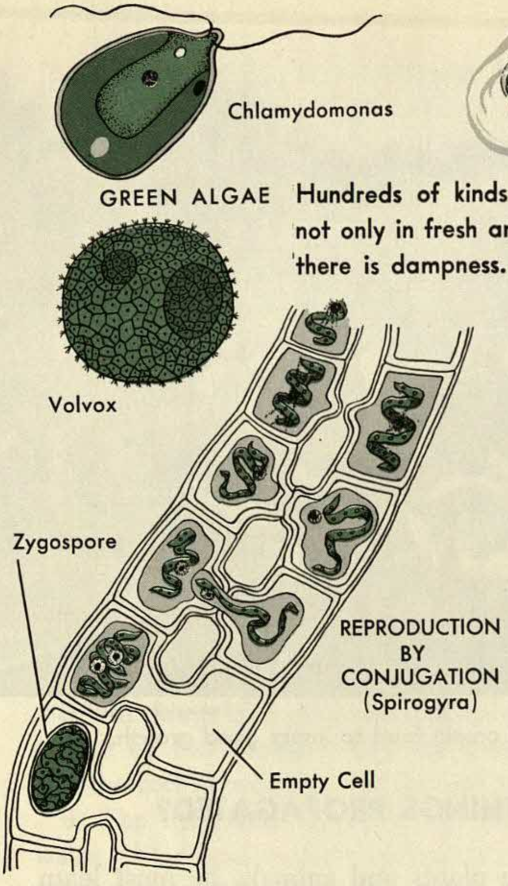
Today, the population of the earth is increasing at a rapid rate. Every day there are many thousands more people in the world than the day before.

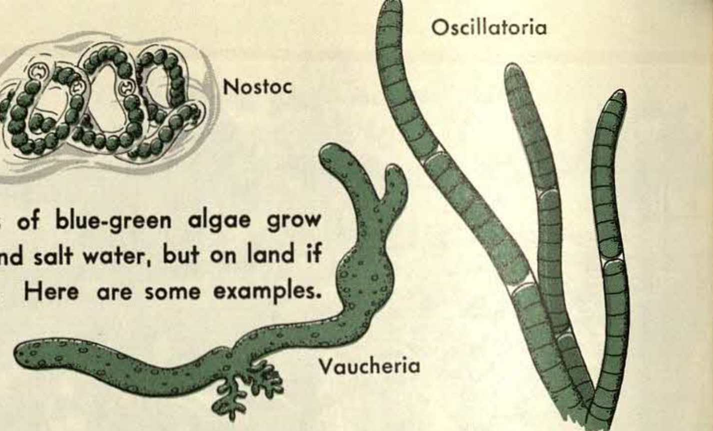
Production of some things can be increased by building better machines for our factories. But food is another problem because no man-made factory can produce it. Man is completely dependent on plants and animals for food. To produce more plants and animals, he must learn how to increase the rate at which they reproduce. But first he must understand how they reproduce.

PLANT PROPAGATION

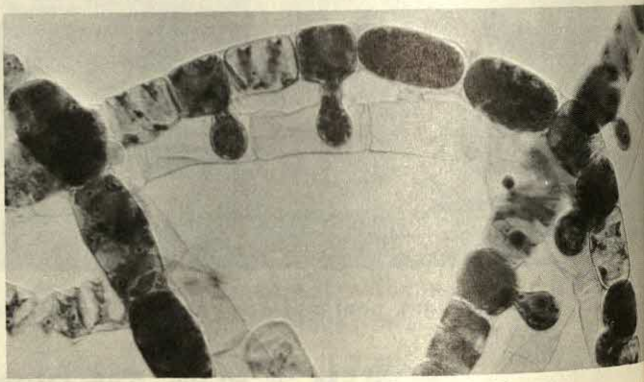
The methods of aiding plant reproduction are called ***propagation.*** Plants can be propagated in a number of different ways, depending upon the manner in which they reproduce. When one thinks about propagating plants, one usually thinks of using seed. But only two groups of plants reproduce in this way.

Now go back and take another look at the table on page 393, where plant groups are listed. Note that one way in which the plants in each group are different from



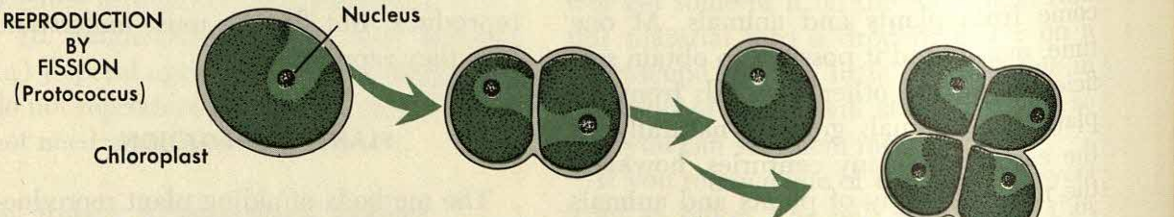


Hundreds of kinds of blue-green algae grow not only in fresh and salt water, but on land if there is dampness. Here are some examples.



General Biological Supply House

Spirogyra in conjugation as protoplast is being transferred through conjugation tube.



Courtesy of the Tokugawa Institute for Biological Research, Tokyo

Chlorella, a one-celled green alga, is grown as a laboratory crop in Japan, where it is processed into different kinds of food, shown at left.

the others is the way in which they reproduce themselves.

Although algae and ***fungi*** (FUN-jye) include plants that reproduce in simple ways, they are important plants in our lives. They will become even more important in the future.

ALGAE

You may have read that one kind of algae will probably be taken along in space ships. It may be used as food, and to clear the air inside the ship of carbon dioxide. You'll learn later how algae can do this. In countries such as Japan, seaweed, a kind of algae, is used as food and in other important ways. Algae are a principal food for ocean fish. When the demand for more food to feed the people of the world can no longer be met by growing crops on soil, the algae of the sea may actually be farmed as a food crop.

Collect some algae from fish tanks, tree trunks, or streams of water, and examine them under a microscope. One kind is the green material which grows in an aquarium that gets too much sunlight; another is the green "moss" that grows on the north side of tree trunks in wet climates. Still another is the green stringy "moss" in brooks and small streams. The familiar seaweed that washes ashore on ocean beaches is also a form of algae.

Reproduction of Algae

The simplest kind of algae are one-celled green plants. See page 404.

These algae reproduce in what may appear to be a simple way. After each cell has grown to a certain size, it divides, or splits in half. The splitting of a cell into two equal parts is called ***fission.*** In this way, each new cell gets half of the cytoplasm and half of the nucleus of the older cell. After the new plant cells grow to a certain size, they may also divide to form new ones. Why cells divide is not completely understood. This is one of the puzzles that biologists are trying to solve.

Many kinds of algae also reproduce when bits of a cell become encased in a covering. These bits are called ***spores.*** A spore contains part of the nucleus and some of the cytoplasm. When conditions are good for growth, each spore develops into a new plant. Sometimes spores form only after a male reproductive cell combines with a female reproductive cell. Although a spore eventually grows into a plant, it is not the same as a seed. As you will learn later, a seed already has a little plant inside of it.

Propagation of Algae

Where algae are used as food, most of them are taken from seas and oceans in which they grow naturally. However, when the demand for them becomes greater than the ocean can supply, better ways of propagating them will have to be developed. In a few places, algae are already being grown in large tanks containing water solutions of chemicals that are necessary for their growth. Under proper conditions, algae can be grown faster in tanks than can farm crops.

Some biologists, interested in space travel, have been at work propagating different kinds of algae in their laboratories. They have been experimenting with them to find which kinds reproduce most rapidly and grow fastest. They have also been studying the best conditions for reproduction and growth of each.

FUNGI

Fungi are also very important in our lives. Yeasts and bacteria are fungi, as are molds and mushrooms. Fungi are different from algae in one important way. Fungi do not have the green coloring matter called chlorophyll. Therefore, they cannot make their own food, but must depend upon other living things for it. Whenever fungi are propagated, it is necessary to supply a suitable food.

Reproduction of Fungi

As you will see, fungi reproduce in the same way that algae do.

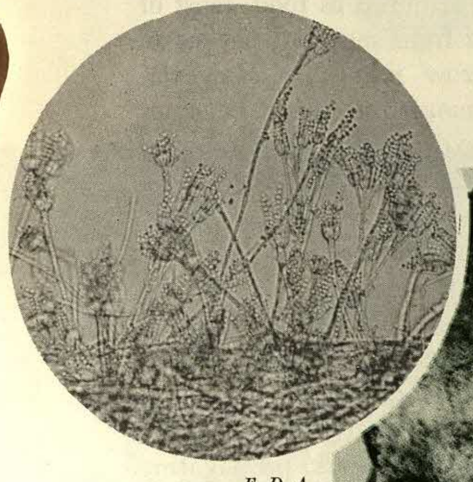
You can grow bread mold by putting a slice of moist bread into a warm, dark place for a few days. Then examine the mold that has formed on the bread through a hand lens or a microscope. You will notice little black specks on the mold. These are the mold spores.

One kind of bacteria can be grown by boiling some hay in water and then putting the mixture into an open jar. If you use a microscope to examine drops of water taken from the jar about a week later, you should be able to find some rod-shaped bacteria in them.

You can also grow yeast in a solution of molasses and water. Add a quarter of a package of yeast to two tablespoonfuls of molasses in a pint of water. The solution should be kept in a warm place for a day. When you examine drops of the solution under a microscope, you will see the large number of yeast cells that have grown in the solution. The yeast will be easier to see if you add a drop of weak iodine solution to the drop you examine. The iodine stains the yeast cells.

In bread mold, left, runners and spores can be seen. In loaf below, mold is feeding on bread. Yeast cell at right is increasing seven fold.

Two photos by Standard Brands—The Fleischmann Laboratories



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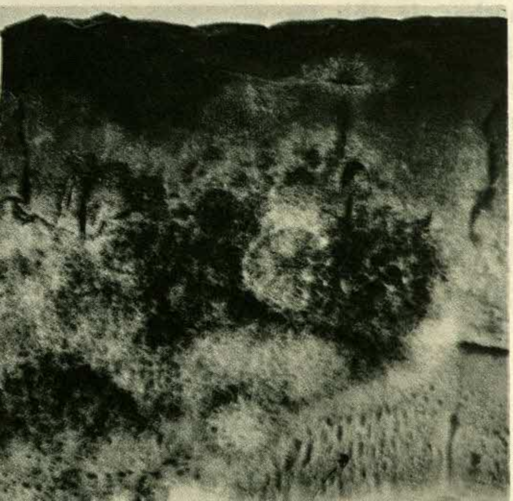
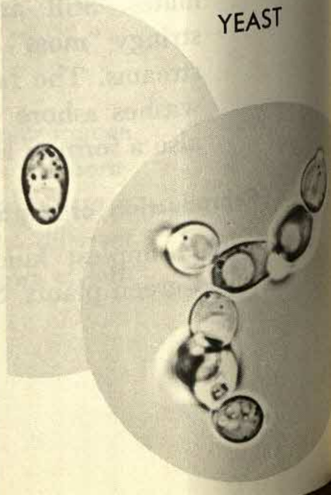


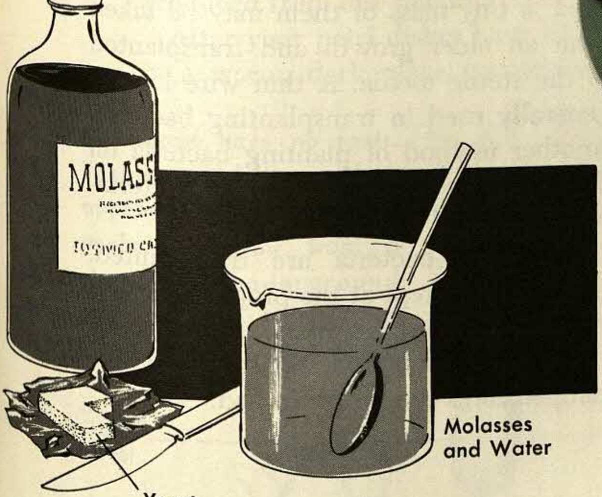


Bacteria

Bacteria are single-celled fungi. The photographs on this page show how three different types of bacteria look through a microscope. Although a few kinds of bacteria cause disease, most bacteria serve the useful purpose of decomposing dead things, garbage, and sewage. Bacteria are also important in the production of butter, buttermilk, and vinegar, and in producing foods such as sauerkraut and dill pickles. Certain disease-producing bacteria are used to make the vaccines and serums that protect you from the diseases which they cause.

Bacteria cells reproduce by dividing. When there is sufficient food and moisture available, and when the temperature is suitable, bacteria reproduce very rapidly. The cells divide as often as once every thirty minutes.

To grow bacteria, food, moisture, and the proper temperature must be supplied. When these are not present, bacteria may produce spores. The spores do not begin to grow until conditions are favorable.



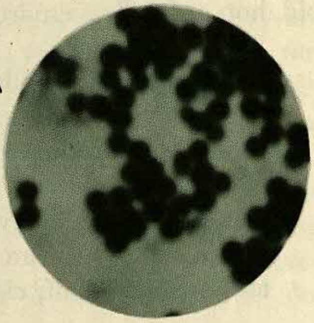
U.S.D.H.W.

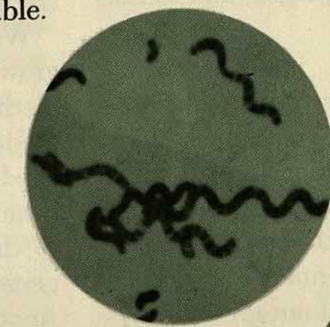
Bacterium has been magnified 15,000 times.

Three main types of bacteria are below.

Chas. Pfizer & Co., Inc., top and bottom

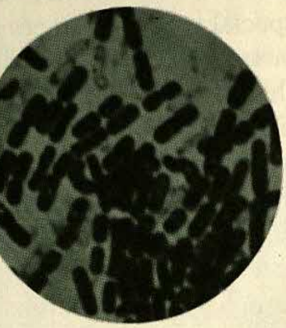
ROUND BACTERIA
(Mag. 3000 X)



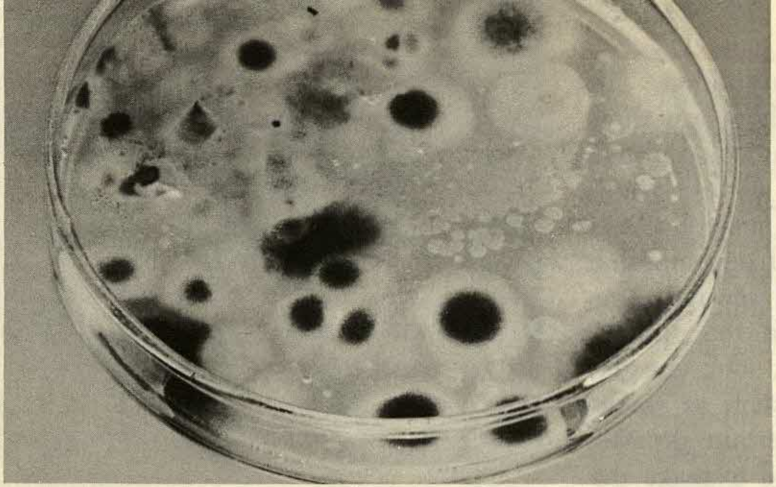


General Biological Supply House

SPIRAL-SHAPED
BACTERIA
(Mag. 2300 X)



ROD-SHAPED
BACTERIA
(Mag. 2500 X)



Colonies of different soil organisms are shown growing on solid nutrients in the petri dish at left.

Chas. Pfizer & Co., Inc.

This is an adaptation that makes it possible for bacteria to live through unfavorable growing conditions such as a dry, cold, hot, or foodless environment.

If each cell divides once every thirty minutes, how many bacteria would be reproduced from one cell in twenty-four hours? Here's the way you figure it. In thirty minutes there would be two; in an hour, four; in an hour-and-a-half, eight; and so on.

Bacteria are grown in laboratories, where they are used for study, or to produce serums and vaccines. Various kinds of food substances are used to feed these bacteria. Some will grow well on boiled potatoes and carrots. Others must have special food substances made out of meat or sugar. Still others will not grow in anything but food substances made out of blood. Foods used in growing bacteria are called ***media.*** They are generally kept in test tubes, or flat dishes called ***petri dishes.*** The media may be in a liquid form, such as a broth, or a more solid form, such as a gelatine. ***Agar,*** a substance obtained from seaweed, is used in making the more solid media.

When the media are in test tubes, cotton plugs are placed in the mouths of the tubes to filter other bacteria out of the air that enters the tubes. The cover of a petri dish serves the same purpose.

The containers of media are heated at high temperatures in large pressure cookers, which are called ***autoclaves.*** The heat kills all bacteria in the media, which are then said to be ***sterile.***

Whenever laboratory workers want to grow bacteria, they use one of several methods for planting them on the sterile media. If only one kind of bacteria is desired, a tiny mass of them may be taken from an older growth and transplanted to the sterile media. A thin wire loop is generally used in transplanting bacteria. Another method of planting bacteria on dishes of sterile media is to allow bacteria-laden material to touch the media.

After the bacteria are transplanted, they must be kept at the proper temperatures. To do this, the dishes of media may be placed in bacteria incubators, where temperatures can be controlled.

You can grow bacteria in this way. Obtain six sterile petri dishes containing agar media (nutrient agar). If there is no way of obtaining these in your school, you might be able to get them from the laboratories of a local hospital, college, or industry.

Remove the cover from each of five petri dishes. Expose the agar in the first dish by coughing into it several times. Leave the second dish open to the air of the room for an hour. Shake your handkerchief over the third and your hair over the fourth. Touch your finger to the fifth. Hold the sixth covered petri dish as a control. After each dish is exposed, replace its cover and fasten it with a strip of cellophane tape. Label each dish according to the way you exposed it. Place all dishes in a warm dark place for several days.

Note the spots on the nutrient agar in the petri dish on page 408. Each spot is a colony. Some are colonies of bacteria; others may be colonies of yeast. Each bacteria colony is made up of millions of bacteria, reproduced from one bacterial cell.

After your petri dishes have been in a warm, dark place for several days, examine them for colonies. How many do you find? How do you explain the different sizes and shapes of the colonies? Which dish has the most colonies? What does this show? How can you be sure?

Yeast Cells

If you examined yeast in the way described on page 406, you saw that they were single-celled. The yeast cells used the sugar in the molasses for food. In doing so, the yeast cells changed the sugar to alcohol and carbon dioxide.

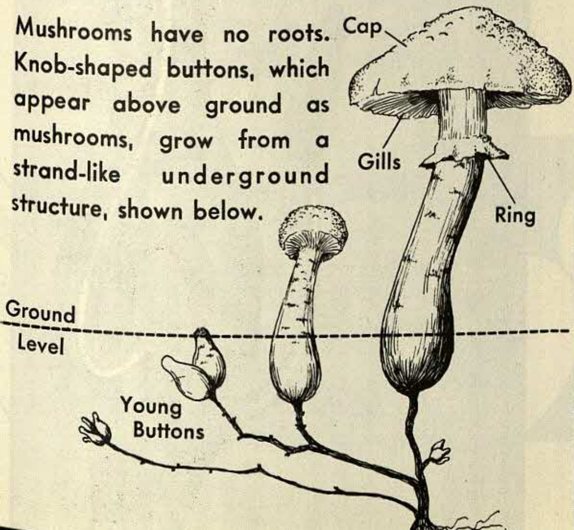
Because yeast cells produce alcohol and carbon dioxide from this sugar, they are important in making bread and in *fermenting* fruit juices. It is the carbon dioxide produced by yeast that causes bread to rise.

The yeast used in bread making is grown in large vats of liquid containing the food material for yeast. After the yeast cells form a thick scum on top of the liquid, they are removed from the vat and pressed into cakes.

Mushrooms

You probably have seen different kinds of mushrooms growing in the woods. Some

Mushrooms have no roots. Knob-shaped buttons, which appear above ground as mushrooms, grow from a strand-like underground structure, shown below.



Mushroom below, left, shows slits on under side of cap. From these slits, mushroom spores drop.

mushrooms are good to eat. These kinds are propagated by the same general methods as those used in propagating bacteria and yeast. Food must be supplied, and temperature and light must be controlled. Mushrooms have a root-like structure of thin strands, which penetrate the food material upon which they grow. When pieces of the root-like strands are planted in suitable food material, new mushroom plants develop.

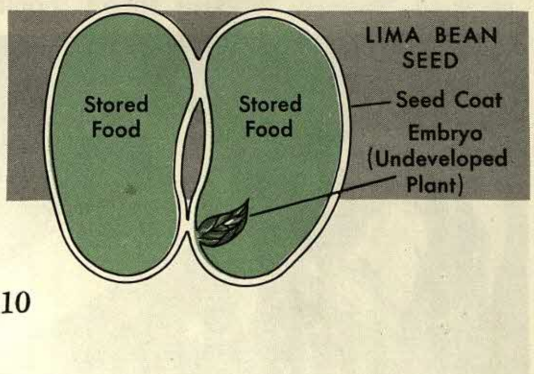
SEEDS

Regardless of the way plants reproduce, it is their cells which bring it about. Remember, that everything which living things do is carried out by their cells.

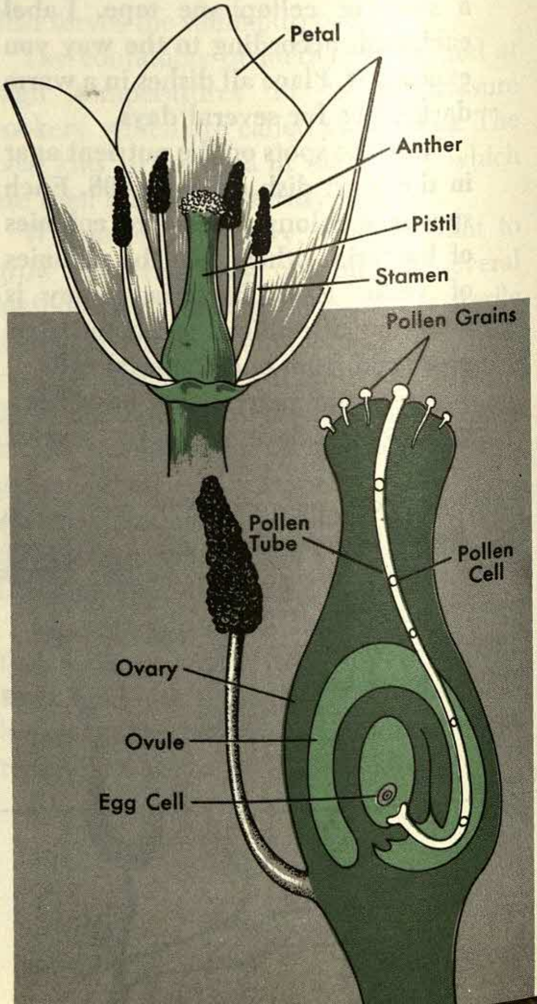
In many-celled plants, such as a tree, the production of new cells by cell division may result, merely, in growth of the plant. At times, however, certain cells may go through a series of cell divisions and finally produce a new plant. Find out how this takes place in producing seeds.

Producing Seeds

You can find the little plant within the seed. Soak some lima bean seeds in water for a day. Then remove the outer covering, called the *seed coat*, and separate the two parts of the seed. These parts contain stored food, as you can see in the diagram on this page. You will find a small, undeveloped plant at one end of the seed. Which part do you think will become the root of the plant as the seed starts to grow? Which will become the leaves?



As you probably know, seeds come from flowers. The parts of the flower necessary for producing seeds are shown on this page. The lower part of the *pistil*, called the ***ovary*** (OH-vuh-ree), produces small structures called ***ovules*** (OH-v-yoolz). Each ovule produces a special kind of cell known as the *egg*, from which the little plant in the seed developed. However, the egg cell alone cannot produce a seed. Another kind of cell is needed.



At the top of each ***stamen*** is the ***anther***, which produces ***pollen.*** Pollen is made up of very small particles called pollen grains, each of which contains a small bit of protoplasm. In this way, a pollen grain is like a spore. Pollen grains are so small that they are easily carried in the air, or by insects that alight on flowers.

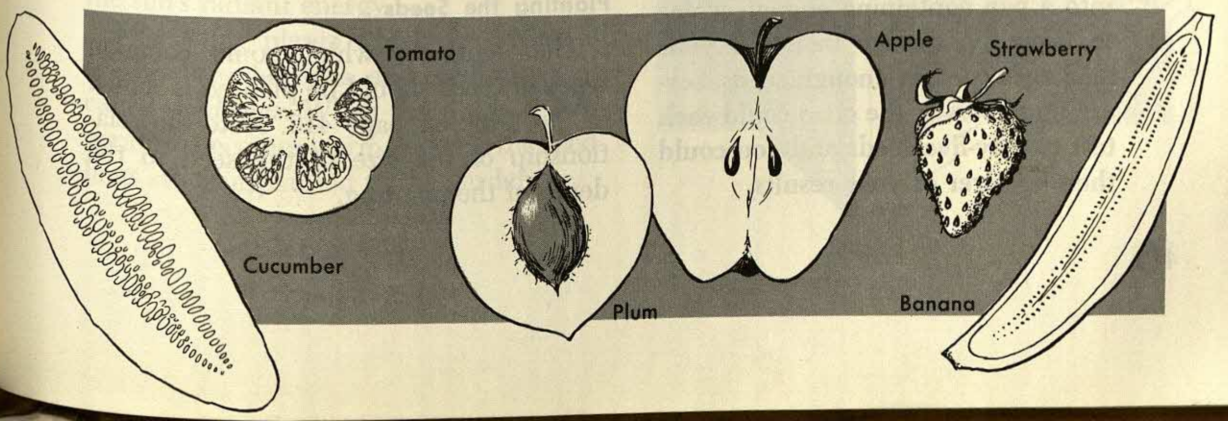
Obtain as many of the following kinds of flowers as you can—tulip, gladiolus, sweet pea, petunia. Remove the petals and locate the pistil, ovary, stamens, and anthers. Do they look the same in all flowers? Shake some pollen into a drop of water on a slide and examine it under a microscope. With a sharp knife split open the ovary. What do you see?

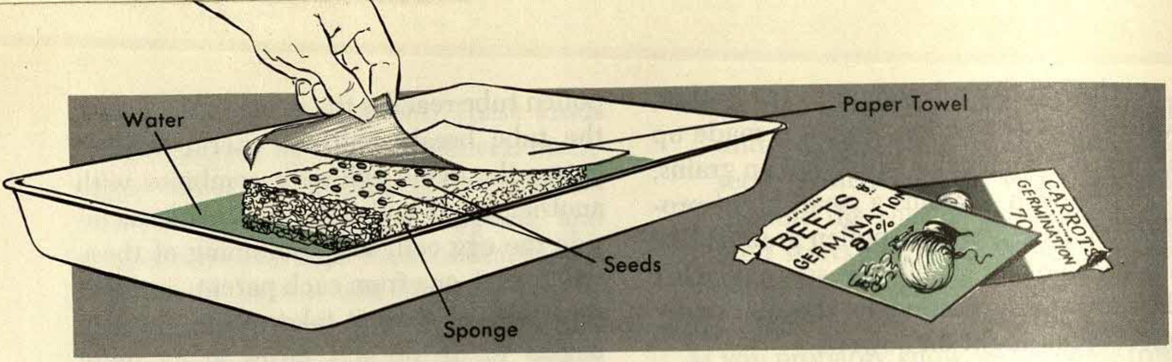
Whenever a grain of pollen is carried to the upper part of the pistil, ***pollination*** is said to take place. If the pollen is transferred from the stamen to the pistil of the same flower, it is called ***self-pollination.*** If the pollen is transferred from the stamen of one flower to the pistil of a different flower, it is called ***cross-pollination.***

After pollination, the grains of pollen begin to grow and form long tubes extending through the pistil into the ovary. As each pollen tube grows, a small body, called a ***sperm nucleus,*** develops within the cytoplasm of the tube. When the pollen tube reaches the ovule in the ovary, the tube breaks and the sperm nucleus enters the ovule, where it combines with another small body, the ***egg nucleus,*** inside the egg cell. The combining of these two nuclei, one from each parent, is called ***fertilization.*** After it takes place, the egg begins to divide and forms many more cells, which grow and develop into the little plant in a seed.

During its early development, this simple plant is called an ***embryo.*** After fertilization, other parts of the ovule develop at the same time into the food-storage parts of a seed. The embryo and stored food are enclosed in the seed coat. In some plants, different parts of the flower develop into a fleshy ***fruit*** after fertilization. The seeds are a part of the fruit. Because two cells, an egg and sperm, must unite to produce a seed, this is called ***sexual reproduction.***

Obtain as many of the following fruits as you can—green pepper, string bean, cucumber, tomato, orange, apple, banana, pumpkin, plum, strawberry. Observe the manner in which their seeds are arranged and attached to them. You might like to draw diagrams to show the different types of seed arrangement. Count the number of seeds in each fruit. In what ways are fruits important in the reproduction of plants?





Germination Tests

After each seed is formed, the small plant inside it must remain alive if the seed is to be of any value in raising plants. If the little plant remains alive, it will begin to grow when the seed is put into a moist, warm place. This early growth is called ***germination.***

Most seed producers test samples of their seeds before they sell them. Usually they print on the outside of each seed package the percentage of seeds that can be expected to germinate. When farmers raise their own seeds, they may test them by taking samples of the seeds to be used for planting and putting them into a moist, warm place. The number of seeds that germinate is counted, and the percentage of germination is determined.

Obtain several packages of seeds upon which the germination rate is given. Check this figure by testing twenty-five seeds from each package. Arrange the seeds on top of a moist cellulose sponge. Lay a paper towel over the seeds. Put the sponge into a pan containing enough water to keep the sponge moist. If your packages contain enough seeds, several members of the class could each test twenty-five seeds and you could then be surer of your results.

Soil Preparation for Seeds

If you have ever had to spade and rake a garden, you have probably wondered why in the world it was necessary. There are several reasons why it is desirable to loosen the soil before planting seeds. Germinating seeds and plant roots need oxygen from the air. Air can enter the soil more easily when the particles are not packed together tightly. Young plant roots can grow out into the soil more easily, and rain water can soak into it more easily, when it is loosened.

You can show that packed soil will absorb water more slowly than loose soil. Cut the bottoms out of two empty tin cans of the same size. Press the bottom of one can about a quarter of an inch into the soil on a path where the soil has been packed down. Press one end of the other can into looser soil near the path. Into each can pour the same amount of water. Compare the time it takes for the water to disappear.

Planting the Seeds

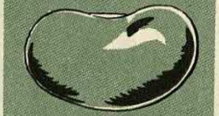
The depth to which some common types of seeds should be planted is shown in the table on page 413. Note the relationship of the size of the seed to the depth of the planting.

By removing one side of a small wooden box and putting a piece of window glass in its place, you can make a box in which you can observe the growth of seeds planted in soil. The box should be filled with soil and the seeds planted at different depths near the glass. The glass should be kept covered with black paper except when you are observing the seed. How could you use such a box to test the facts given in the table on this page?

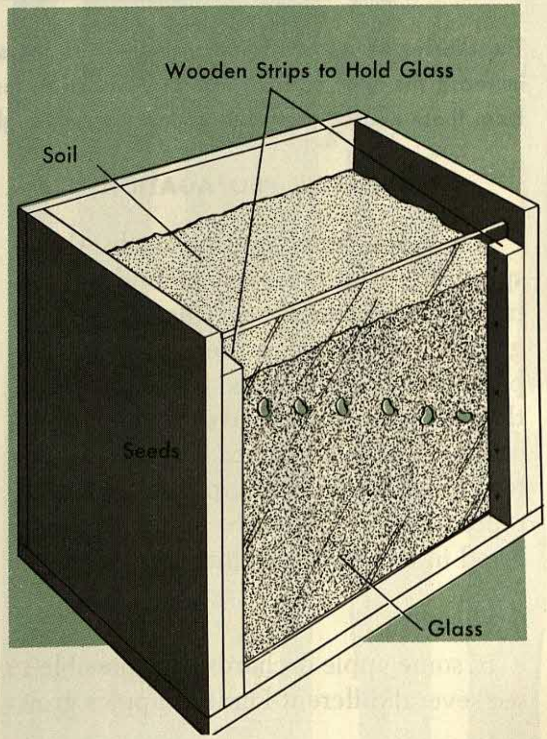
Before the embryo plant in the seed can grow, it must obtain energy and materials to build more protoplasm from the food that is stored in the seed. The stored food, therefore, has to be digested into a simple form that can be used for these purposes. The chemical processes that digest the food require both moisture and heat.

If you want to get seeds to germinate and grow in the spring before it is warm enough outside, you can use *greenhouses, hotbeds,* and *coldframes.* Radiant energy from the sun is the principal source of heat in all of these structures, as you can see on page 414. Manure can be buried in the soil because it becomes heated as bacteria cause it to decompose. Steam pipes or electric heating elements may also be buried in the soil. Cold frames have no heat source other than that of the sun's radiant energy.

The young plants which are grown in greenhouses, hotbeds, and coldframes are called *seedlings.* When the outdoor temperature becomes warm enough, the seedlings are transplanted to the garden.

Seed	Comparative Size	Planting Depth in Inches
Bush Lima Bean		2
Squash		1
Corn		1
Radish		½
Tomato		½

Depth at which seeds should be planted usually depends upon size of seed. If seeds are planted too deeply, plants may never come up.



J. C. Allen & Son

The shorter waves of radiant energy from the sun pass through the glass of the greenhouse and increase the heat of soil and other materials inside. Because the longer waves of radiant energy from these heated materials cannot pass through the glass so easily, much of this heat is trapped.

VEGETATIVE PROPAGATION

Have you ever noticed little shoots sprouting from the eyes, or buds, of potatoes? Sometimes new plants may be grown without using seeds at all. Some plants can be propagated by using parts of their roots, stems, or leaves. Reproduction of plants in this manner is called ***vegetative propagation.*** Some plants commonly reproduced by vegetative propagation are listed in the table at right.

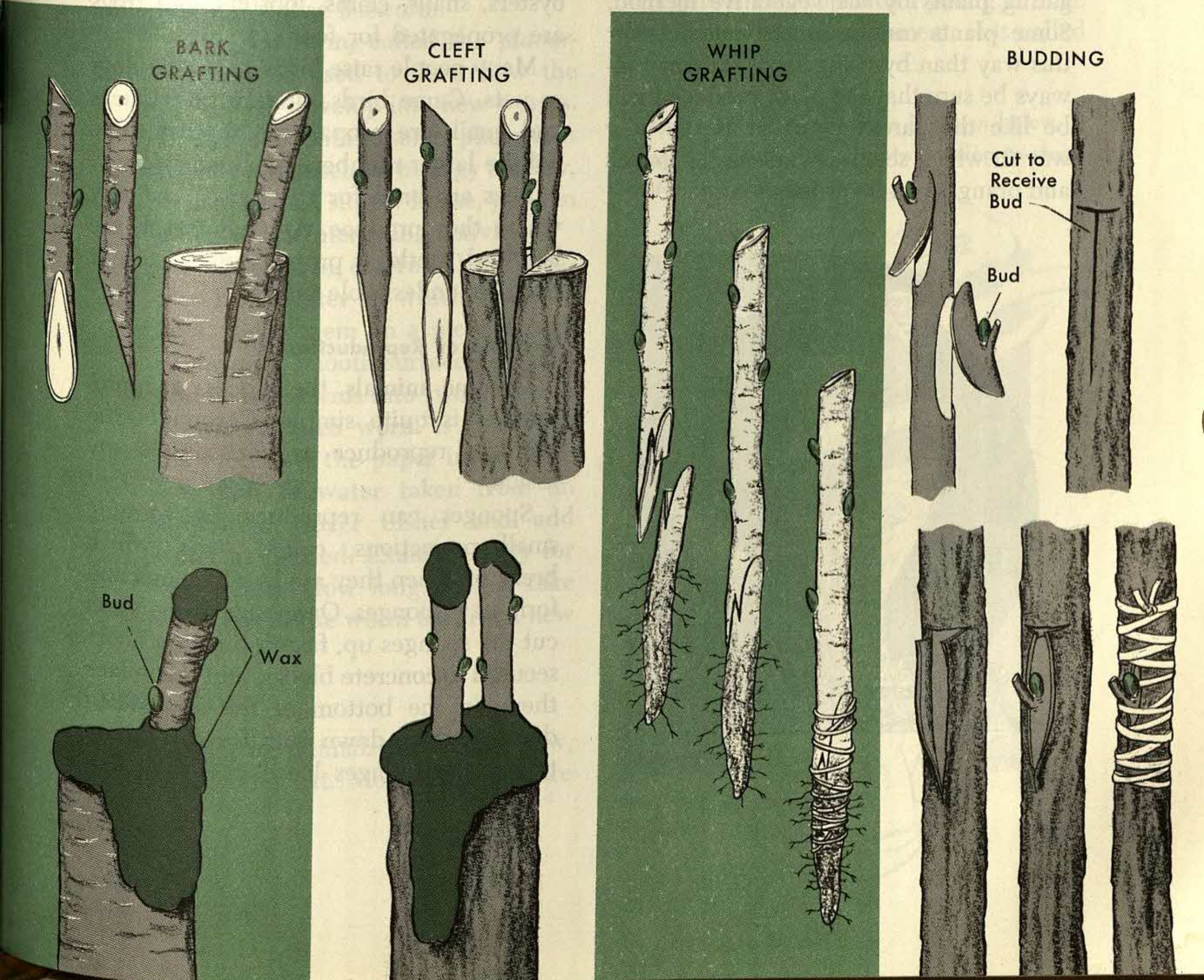
Plant	*Part Used*
Asparagus	Root cutting
Sweet potato	Root cutting
Strawberry	Stem (runner)
Geranium	Stem cutting
Fern	Stem (runner)
Tree	Stem cutting
Begonia	Stem or leaf cutting
Tulip	Stem (bulb)
Crocus	Stem (bulb)
Dahlia	Stem (tuber)
White potato	Stem (tuber)

Grafting

In some apple orchards, it is possible to see several different kinds of apples grow-

Plant	*Plant Onto Which Grafted*	*Time of Year*
Almond	Root of almond or peach	Spring
Apple	Root of apple seedling	Spring
Apricot	Stem of apricot or peach	Winter
Cherry	Stem or root of cherry	Winter
Lemon	Stem of lemon seedling	Winter
Orange	Stem of orange seedling	Winter
Peach	Root of peach	Early fall
Pear	Stem of pear seedling	Winter
Pecan	Root of hickory	Fall
Rose	Root of rose	Winter

Four methods of grafting are shown below. The growing layer of cells immediately under the bark must be attached when grafted in order to have the grafted stem or bud grow. Wax protects graft.



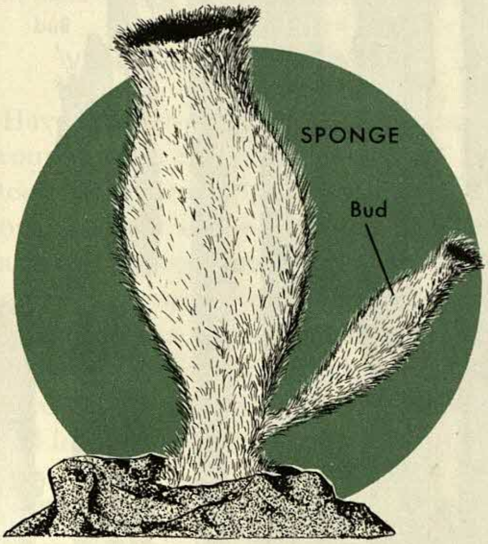
ing on one tree. Plants such as fruit trees are propagated vegetatively by a method called ***grafting.***

In this process, a stem or a bud of one plant is attached to the root or stem of another plant in such a manner that the two parts grow together.

Various methods may be used in grafting a stem or a bud to another stem or root. Four common methods are illustrated on page 415, and the names of some plants commonly propagated by grafting are listed in the table on the same page.

Advantages of Vegetative Propagation

There are several advantages to propagating plants by the vegetative method. Some plants can be grown much faster this way than by using seeds. You can always be sure that the plant produced will be like the parent plant. It is the only way in which seedless varieties of grapes and oranges can be propagated.



Some varieties of fruit trees have good quality fruit but poor roots and, therefore, produce very little fruit. By grafting a stem or bud from such a tree onto the stem or roots of a tree with a good root system, you can obtain a tree that will produce a quantity of high-quality fruit.

Grafting has also made it possible to grow several different varieties of related fruit on the same tree.

ANIMAL PROPAGATION

A number of different kinds of animals are raised for man's use. Cattle, hogs, sheep, chickens, as well as fish, turtles, oysters, snails, clams, lobsters, and frogs are propagated for food.

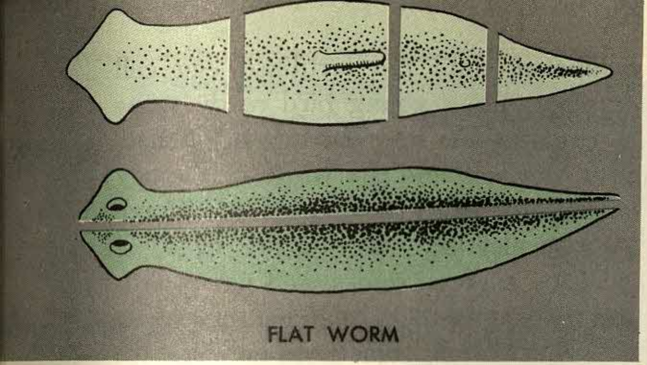
Many people raise birds, cats, and dogs as pets. Game birds, such as wild ducks and quail, are propagated so that there will be larger numbers for hunters.

Bees are bred for the honey and wax which they produce. Another insect, the ladybird beetle, is propagated because it destroys undesirable insects.

Methods of Reproduction

In some animals, the process of reproduction is quite simple. Certain of the protozoa reproduce as bacteria do—by fission.

Sponges can reproduce by forming small projections, called ***buds,*** which break off when they are large enough and form new sponges. Or sponge farmers can cut the sponges up, fasten them on hooks secured to concrete blocks, and then place them on the bottom of the sea. When divers later go down with fork-like hooks to pry the sponges loose, they will find



that large sponges have grown from the little pieces planted by the sponge farmers. This process is like vegetative propagation in plants.

Flatworms can also be cut into a number of pieces. Each piece will then develop into an entire flatworm.

One flatworm, called the *planarian*, can be used to show how the pieces will develop into new worms. If you can obtain some planarians from the high school biology teacher, or a biological supply house, you can observe this interesting activity.

With a spoon, carefully lift planarians from water in which they are kept. Place them on a piece of wet paper on a smooth surface. Cut several of the worms into two pieces as shown. As each worm is cut, wash the pieces off the paper into a shallow dish of water taken from an aquarium. Cover dishes and add water as needed. Examine daily for two weeks. How long does it take each part of the worm to form a new worm?

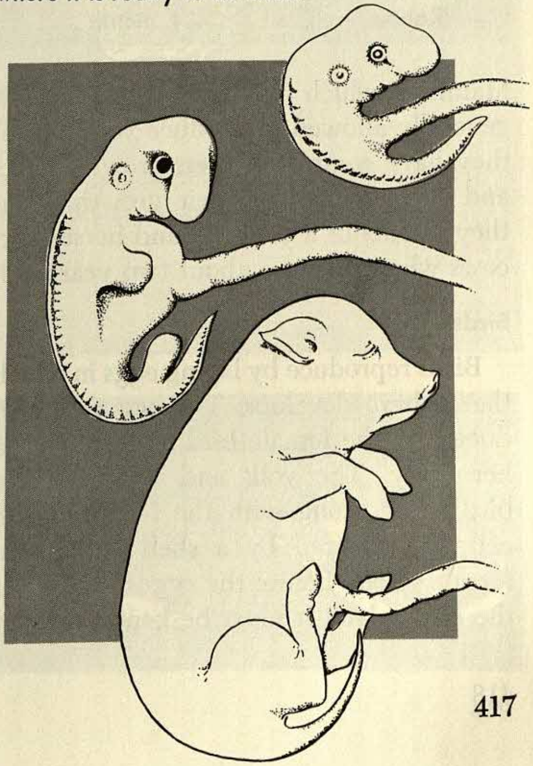
Mammals

Mammals are animals such as the cow, horse, dog, and cat. Most mammals are born alive—fully formed—and fed with milk from the mother's body. Humans are mammals.

Most of the animals that man propagates reproduce by the union of a male cell, called the sperm, and a female sex cell, called the egg. Such a process is known as sexual reproduction. As you will recall, flowering plants produce seed by sexual reproduction.

Two sexes, male and female, are necessary for reproduction in mammals. The female produces egg cells and the male produces sperm cells. The egg is fertilized within a special part of the female's body by the sperm. After the egg is fertilized, it begins to develop into a young animal. During its early development, it is called an embryo.

Development of pig embryo is shown below. It takes four months for a pig to develop to stage where it is ready to be born.



Although each developing embryo has its own blood system, it also has a special structure through which its blood can obtain food and oxygen from its mother's blood. For this reason, it is important that the mother be properly cared for during the period that the embryo is developing in her body. The length of time it takes for a fertilized egg to develop into a young animal that is ready to be born varies among mammals. See table below.

Period Between Fertilization of Egg And Birth of Young in Certain Mammals

Mammal	*Number of Months*
Horse	11 months
Donkey	12 months
Cow	9½ months
Sheep	5 months
Hog	4 months
Dog	2 months
Cat	2 months
Rabbit	1 month

Mammals which man propagates are not generally allowed to produce young until they have completed their growth. Hogs and sheep complete their growth when they are about a year old and horses and cows when they are about two years old.

Birds

Birds reproduce by laying eggs in which the embryo develops. The egg cell, produced by the female bird, is fertilized in her body. The yolk and white of the bird's egg, along with the fertilized egg cell, are covered by a shell within the female's body before the egg is laid. After the egg is laid, it must be kept warm, or ***incubated,*** until the fertilized egg cell develops into a young bird ready to be hatched. By the time the egg is hatched, all of the yolk and the white of the egg have been used by the young bird as food.

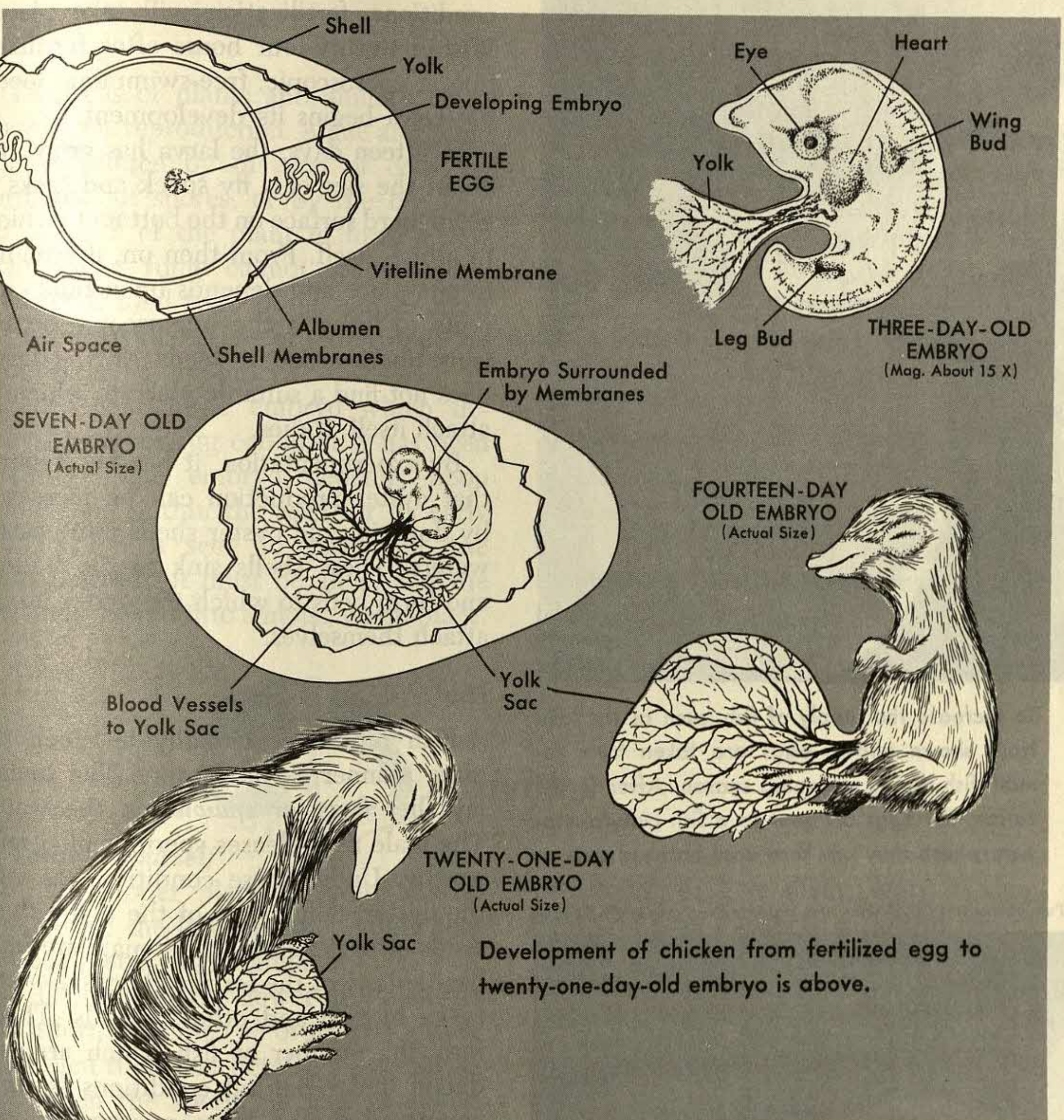
By collecting the fertile eggs of chickens, turkeys, ducks, and game birds and incubating them, man can propagate these birds. Hens sometimes incubate the eggs, but large electrically operated incubators are generally used. In hatcheries, incubators can hold as many as 4,000 chicken, turkey, or duck eggs.

After the young birds are hatched, it is necessary to provide suitable shelter for them. Sometimes older birds look after them, but usually the young birds are kept in ***brooders.*** These sheds, or buildings, contain heating units around which the young birds gather to keep warm. Suitable food and water are also supplied in a brooder.

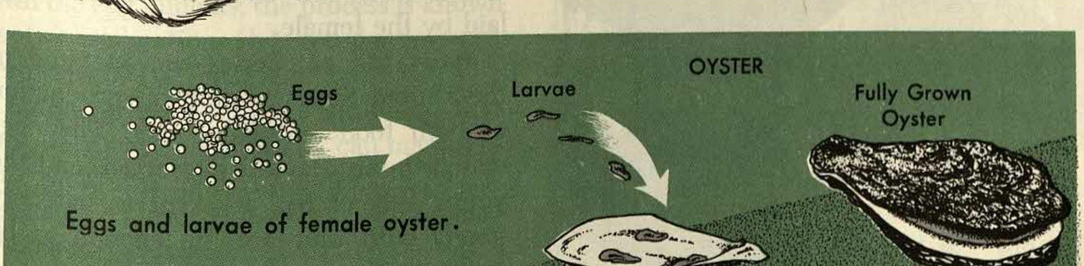
Oysters

Oysters are a valuable source of protein food, obtained from the coastal waters of the United States. In 1883, Maryland's half of Chesapeake Bay produced fifteen million bushels of oysters; in 1957–58, it yielded only a little more than three and a half million bushels. This loss in food production is estimated to be equal to the meat that could be obtained from 200,000 fat beef cattle. Since 1883, much has been learned about the propagation of oysters. The application of this knowledge is doing a great deal toward increased production.

Both the eggs of the female oyster and the sperm of the male are ejected into the open water where, under proper


Shell
Yolk
Developing Embryo
FERTILE EGG
Vitelline Membrane
Albumen
Air Space
Shell Membranes
Eye
Heart
Wing Bud
Yolk
Leg Bud
THREE-DAY-OLD EMBRYO (Mag. About 15 X)
Embryo Surrounded by Membranes
SEVEN-DAY OLD EMBRYO (Actual Size)
FOURTEEN-DAY OLD EMBRYO (Actual Size)
Yolk Sac
Blood Vessels to Yolk Sac
TWENTY-ONE-DAY OLD EMBRYO (Actual Size)
Yolk Sac

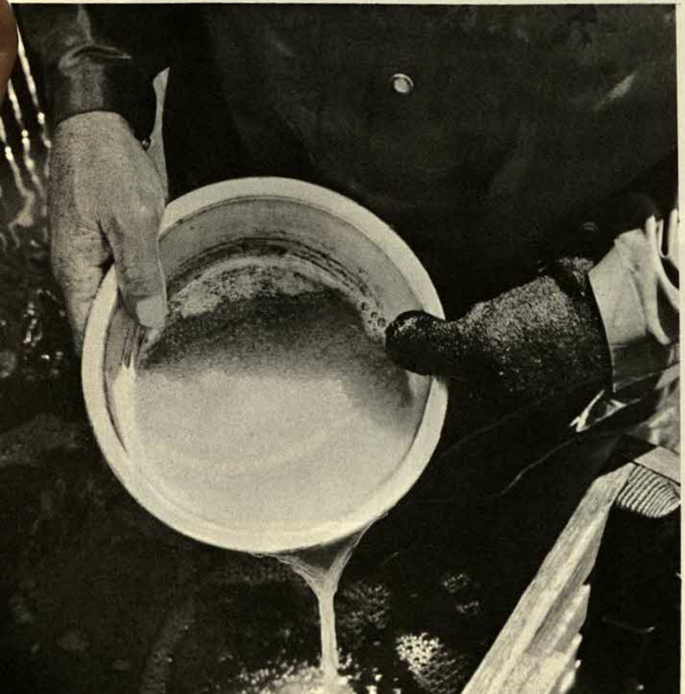
Development of chicken from fertilized egg to twenty-one-day-old embryo is above.



Eggs and larvae of female oyster.

To increase the supply of fish, such as the lake trout shown above, eggs are taken from female fish during spawning season. After fertilization, the eggs are sent to a fish cultural station, where they are kept until hatched out.

Two photos from U. S. Fish and Wildlife Service—P. P. Haddon



conditions, fertilization will take place. Within twenty-four hours after fertilization, a microscopic, free-swimming, feeding larva begins its development.

In fifteen days, the larva has grown to about the size of a fly speck and seeks a clean, hard surface on the bottom to which to attach itself. From then on, it remains in one place and depends upon tidal currents to bring it the microscopic organisms upon which it feeds. If the larva does not find a suitable place to which to attach itself, it dies.

By experimentation, it has been found that oyster production can be increased by dumping old oyster shells into coastal waters. These shells sink to the bottom and form beds to which the oyster larvae attach themselves.

Fish

Fish reproduce sexually in much the same manner as do oysters. The female lays her eggs, or ***spawns,*** in the water. The male fish releases sperm, called ***milt,*** nearby. Under these conditions, as with the oyster, only a few of the many thousands of eggs laid by the female are fertilized. Many of the fertilized eggs are later eaten by fish and other animals. Therefore, the number of fish which are produced under natural conditions is small compared to the large number of eggs laid by the female.

Many fish hatcheries are operated in the United States to step up production of both food and game fish. The eggs which the fish lay are protected, and the young fish, or ***fry,*** are kept in hatchery ponds until they are big enough to be put into streams.

SUMMARY

The cells of plants and animals bring about their reproduction. Algae and fungi can reproduce by division of cells, by formation of spores, or by the breaking off of parts of the plant to form a new plant. Since fungi cannot produce their own food, food from other sources must be made available before they will reproduce in any quantity.

Seeds contain an embryo which develops from an egg cell after it has been fertilized. The embryo depends upon stored food within the seed for its early growth. For a seed to germinate, the embryo within it must be alive, and the seed must be put into a moist, warm place.

In propagating plants from seeds, man attempts to select those which will germinate and then provides them with the conditions that will encourage growth.

Under certain conditions, cells in roots, stems, or leaves of plants may begin to divide and produce another plant. Plants can be propagated by separating parts of roots, stems, or leaves from the parent plant and providing them with conditions suitable for growth. Vegetative propagation is used to hasten the propagation of plants and to insure the production of plants like the parent.

Most of the animals that man propagates reproduce sexually. Man attempts, therefore, to control conditions so more fertilized eggs will develop.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. The part of the flower in which the seed is formed is the (a) ovary (b) anther (c) pollen tube (d) petal.

2. When the sperm nucleus combines with the egg nucleus, the process is known as (a) pollination (b) germination (c) fertilization (d) congregation.

3. Bacteria are single-celled plants that (a) are always harmful (b) can manufacture their own food (c) should all be destroyed (d) reproduce by dividing into two cells.

4. In propagating fungi, it is necessary to (a) keep them cool (b) provide them with food (c) give them plenty of sunlight (d) soak the seeds in lots of water.

5. New plants produced by vegetative propagation (a) never produce seeds (b) are always free of disease (c) are like the parent plant (d) are never as strong as the parent plant.

6. The developing embryo of a chicken is not like that of a pig because (a) it does not develop from a fertilized egg (b) it obtains its food in the same manner (c) it grows more slowly (d) it develops outside the female's body.

7. The eggs of oysters are fertilized (a) in the mother's body (b) by sea water (c) by sperm (d) by spores.

8. Most of the animals man propagates reproduce by (a) sexual reproduction (b) vegetative propagation (c) forming spores (d) spawning.

9. Oyster eggs are fertilized in the (a) male's body (b) female's body (c) egg roe (d) open water.

10. Algae differ from fungi in that they (a) reproduce by fission (b) contain chlorophyll (c) cannot make their own food (d) are smaller.

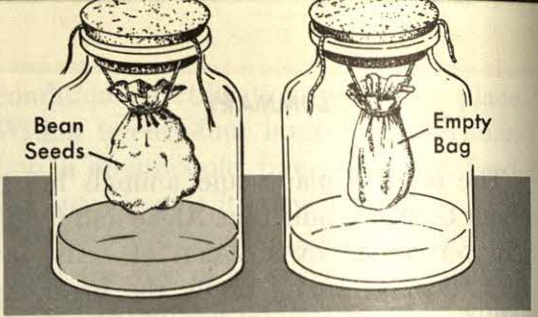
B. Conducting Experiments

1. Do an experiment to find the temperature at which yeast can be killed. Use the procedure described on page 406 for growing yeast. Prepare several batches. Heat the water in each batch to a different temperature and set all batches aside for one day. How can you tell if the yeast cells have been killed? Why would it be important to put each batch into a clean bottle and plug the mouth with cotton?

2. Do an experiment to find out if bread mold will grow faster on one kind of bread than on another. Use white bread, whole-wheat bread, rye bread, and any other kind of bread you can get. Remember that the bread must be kept in a warm, moist place. For this to be a controlled experiment, what must be the same for each kind of bread? How will you judge the rate at which mold grows on bread?

3. Do germinating seeds give off carbon dioxide as food is used by the growing plants within them?

Obtain the following materials—two bottles, stoppers to fit them, two pieces of cheesecloth, each about six inches square, twenty-five germinating bean seeds, and limewater.



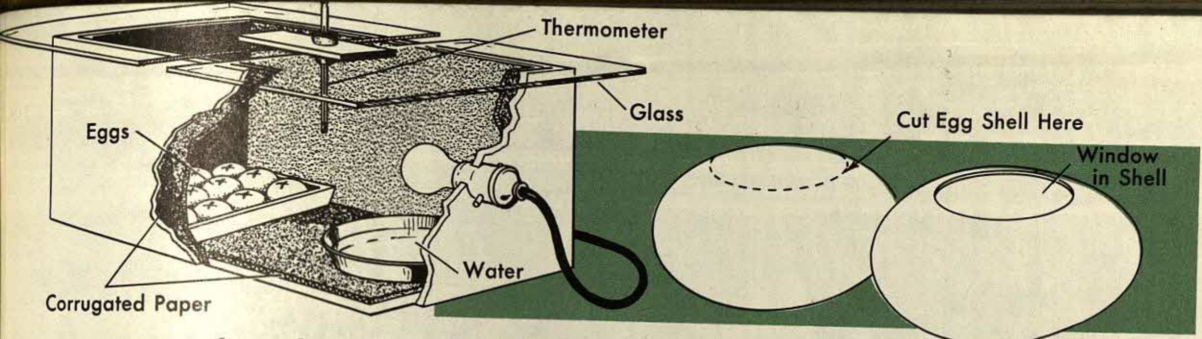
Pour about an inch of limewater into each of the bottles. Tie twenty-five germinating seeds into a cheesecloth bag and suspend them in the bottle half an inch above the limewater. Suspend an empty cheesecloth bag in the second bottle in the same manner.

Observe the limewater. When limewater takes up carbon dioxide, it becomes cloudy. Which bottle is your control? How long is it before you notice any change in the limewater?

How do you know that (a) all seeds act like these seeds and (b) carbon dioxide is the only thing that will cause limewater to become cloudy?

C. Observing Embryonic Development

Use a wooden box to build an incubator about one foot square on the end and twenty-four inches long. You will need two boards, or panes of glass, to cover the box, an electric lamp, a thermometer, a pan of water, a tray, and a dozen fertile eggs. Line the box with corrugated paper to insulate it. Install the lamp, which is to serve as the heating unit, in one end of the box as shown. The pan with the water in it should be placed under the lamp. This pan is the ***humidifier.*** Place the tray in the position shown. Suspend the thermometer between the two boards, or panes of glass. Turn on the lamp and keep a record of temperature in the incubator for two days. Regulate the tem-



perature by making the crack in the cover wider, or by changing the size of the lamp until you get the temperature to remain constant at a 103°F.

After the incubator is properly regulated, place the eggs in the tray. Mark each egg with an X on the side that is up. Each day the eggs should be turned so that one day all the X's are up, the next day all are down. Keep water in the pan.

After four days, remove an egg and place it on a warm cloth pad. With fine-pointed scissors, puncture the shell and cut a hole in the top. Remove the shell and observe the embryo. It may be that you will have to pour the contents of the egg into a small dish to observe the embryo. Open one egg each day to observe the way the embryo grows and develops.

What is necessary before a little chick will develop in the egg? What are some of the first parts of the embryo that you can see? How could you tell that all of the eggs that you used were fertile?

D. Observing Egg Development

Each species of frog lays its eggs at a different time, depending upon the surrounding temperature. The common leopard frog (*Rana pipiens*) lays its eggs in shallow ponds or streams in early spring. In southern states, you may find the jelly-like masses of the leopard frogs early in March. In northern states, it may be as late as April before you find them.

When you do find such jelly-like masses of eggs, collect them in a jar or pan. Put the eggs in a large jar or aquarium filled with the pond water in which you found them and observe their development from day to day.

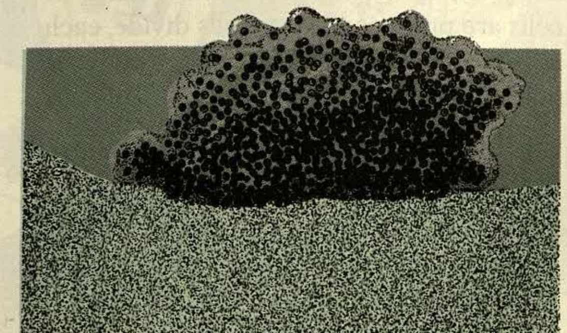
Use encyclopedias or college biology books to find out (a) where the frogs spend the winter (b) how the female eggs are fertilized (c) how many eggs the female lays (d) what the light and and dark parts of the egg are (e) how the color and shape of the egg affect its temperature (f) how long it takes for the eggs to hatch and (g) how the eggs develop into a frog.

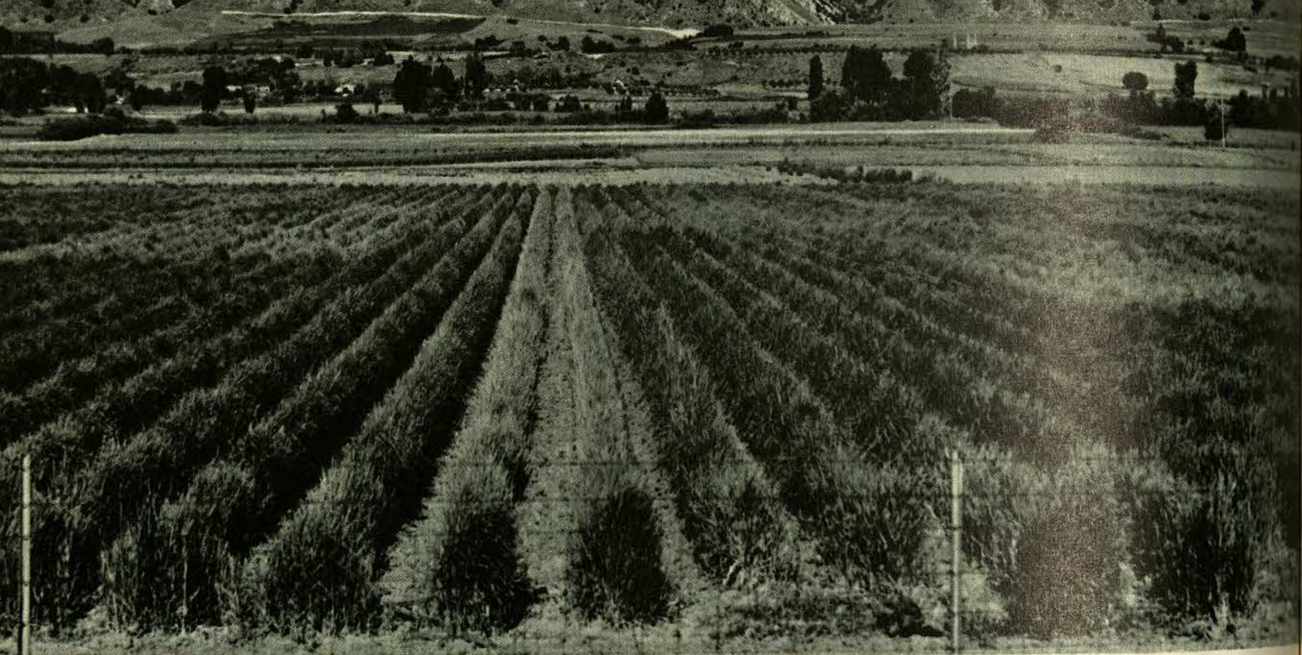
E. Preparing Reports

Collect information from encyclopedias for reports on the following topics

1. The use of bacteria in processing foods and other important materials
2. Yeast as a future source of food
3. Growing mushrooms for food
4. The use of seaweeds for food and other purposes
5. The treatment of seeds to hasten germination

FROG EGGS





U.S.D.A.

When plants obtain the materials they need, they attain full growth. Nitrates were applied to the field shown above, with the exception of the center strip. The plants there appear to be stunted.

PROBLEM 3: HOW DO LIVING THINGS OBTAIN THE MATERIALS THEY NEED?

At the time an egg cell in a flower is fertilized, it is extremely small. In fact, you would have to use a good microscope in order to see it. But as soon as this microscopic speck is fertilized, it begins a period of development that eventually results in a full-grown plant.

DEVELOPMENT OF CELLS

By repeated cell divisions, millions of cells are produced. Furthermore, as this happens, a number of different kinds of cells are produced. After cells divide, each new pair must grow. The full-grown plant not only looks different, but it is millions of times larger than the one cell from which it developed.

All living things that reproduce sexually began their development from a single fertilized egg cell. As complicated as man may think he is, he, too, was once only a single cell.

Even among the single-celled plants or animals that reproduce by the splitting of one cell into two cells, there is development after the splitting takes place. Each half grows to the size of the original cell.

Materials for Growth

For a cell to grow, it must increase the amount of its protoplasm. It cannot create more protoplasm from nothing. However, it can build, or synthesize, it from more of the materials out of which it was originally formed. The cell must obtain these building materials from its environment.

You can show what would happen if cells divided without growing. Cut a piece of notebook paper into two equal parts. This represents one cell division. Now cut each of these two pieces into two equal parts. Cut each piece into two equal parts two more times. Now put all the pieces together. You will find that they are no bigger than the original piece. They have grown in number, but they have not grown in size.

This is the way an egg grows right after it is fertilized. Soon, however, each of the cells begins to grow by getting bigger. Before this can happen, cells must get the materials they need for growth.

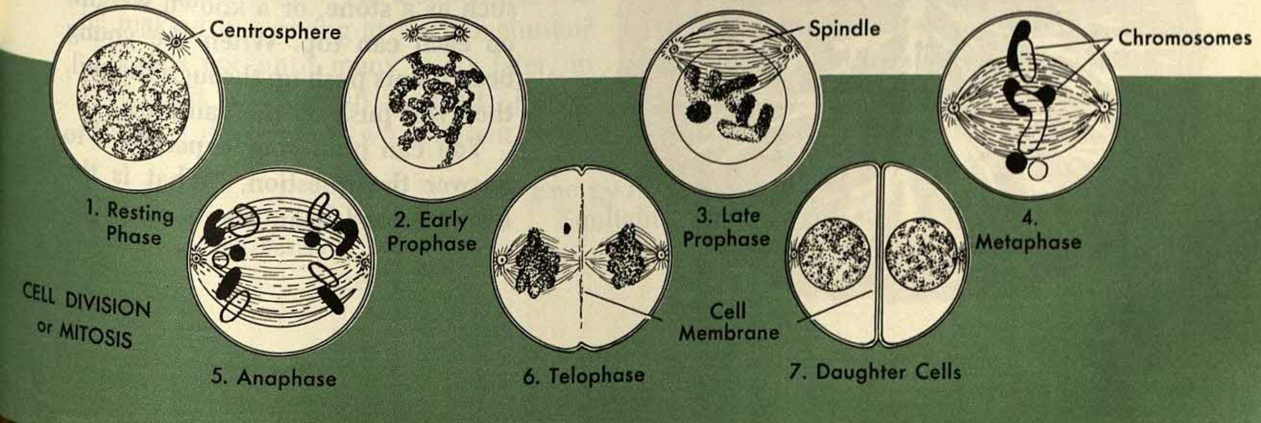
As you learned in Unit 2, the materials, or matter, in our environment consist of ninety-two different natural elements. About thirty-five of them are important to living things. Carbon, hydrogen, oxygen, and nitrogen are the most common elements in the protoplasm of all living things. Sodium is needed by animals, but not by plants. Other elements such as iodine, manganese, zinc, and fluorine are needed by some living things, but not by others. Although living things are alike in needing certain of the same basic elements, they differ in their needs for other elements. All living things must obtain these elements from their environment.

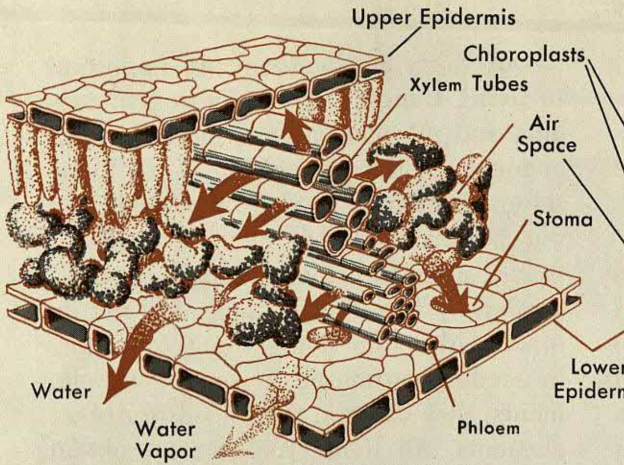
Materials for Energy

In addition to materials out of which more protoplasm can be synthesized, living things need energy. Energy is the capacity to do work, and work is done when something is moved.

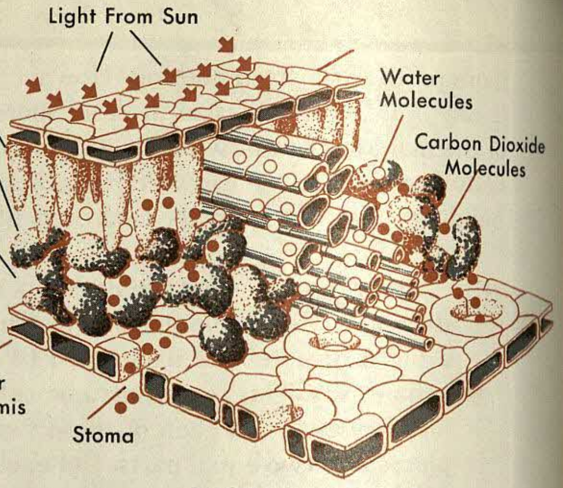
For what kinds of work do living things need energy? Some of the more obvious kinds of work are running, crawling, flying, and swimming. But living things do many other kinds of work. The young plant that pushes away the soil in growing upward from the place where the seed was planted is doing work. The flow of

The different phases which occur in the division of a fertilized egg are diagrammed below. After fertilization of the egg, it divides into two cells. The nuclear material in the egg forms paired chromosomes, which split. These chromosomes then arrange themselves so that they are equally distributed to each of the new cells which have been created in the course of the cell division.





TRANSPIRATION



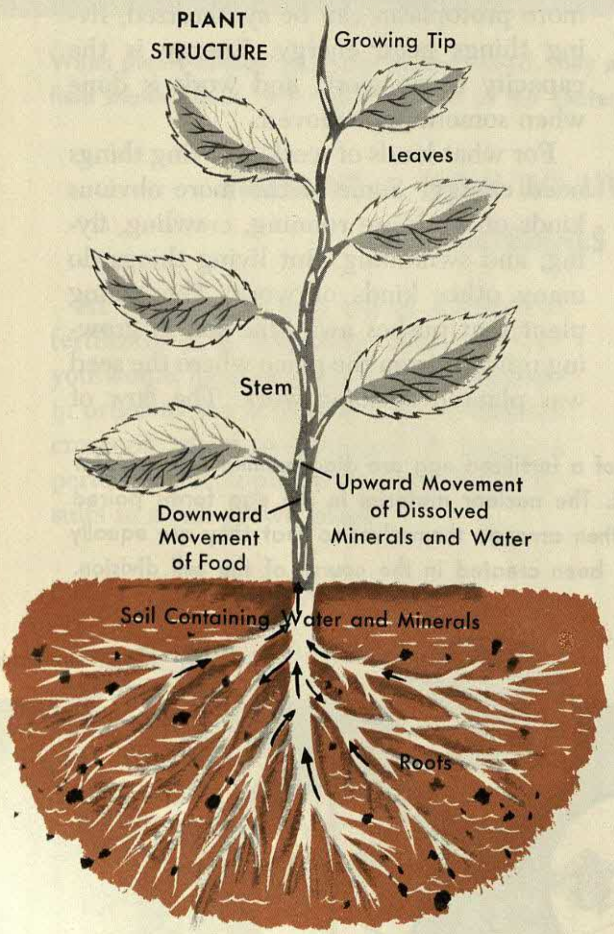
PHOTOSYNTHESIS

cytoplasm in cells is work. Work is being done when cells divide. Cells are doing chemical work when they build more protoplasm. For these and the many other activities of living things, energy is needed. As you shall see later, the energy to carry on these activities must also come from materials which living things obtain from their environment.

You can experiment to find out how much of a load young bean plants can move. Plant five or six bean seeds in each of several cans of sandy soil. Punch holes in the bottom of each can before you put in the soil. Keep the soil well watered.

Place the top that was originally cut from each can over the soil in that can. Then place a small object such as a stone, or a known weight, on each can top. When the young bean plants push up through the soil, they will push on the can tops.

You can plan your experiment to answer the question, "What is the heaviest load bean plants can lift?"


PLANT STRUCTURE
Growing Tip
Leaves
Stem
Upward Movement of Dissolved Minerals and Water
Downward Movement of Food
Soil Containing Water and Minerals
Roots

NEEDS OF GREEN PLANTS

It was believed at one time that plants obtained all of their materials for growth from the soil. It had been observed that plants had to receive water from the soil in order to grow. But the trunk, branches, and leaves of trees were something more than water. The materials stored in roots, stems, and seeds of plants were quite different from water. It was believed, therefore, that plants took some kinds of materials out of the soil in addition to water.

Two Important Experiments

About three hundred years ago, a Belgian physician, van Helmont, became interested in the problem of plant nutrition. Because he was a scientist, he devised an experiment to answer the question, "Do plants take anything other than water from the soil?"

Van Helmont carefully weighed a barrel of soil from which all water had been removed, and then planted a tree seedling in it. Only rainwater was added to the soil. Can you see why? After five years, a tree weighing 169 pounds had grown in the barrel. When the tree was removed and the soil weighed, van Helmont found that the soil weighed only two ounces less than its original 200 pounds. He concluded, therefore, that water alone had produced the tree. What assumptions was he making in arriving at this conclusion?

It was not until many years later, in 1773, that an English scientist, Joseph Priestley, discovered two different kinds of "air." One kind he called "fixed air," the other "dephlogisticated air." Priestley's "fixed air" was later identified as carbon dioxide and his "dephlogisticated air" as oxygen.

Priestley did experiments in which he found that when a green plant was put into a covered glass container filled with air, it soon died. He found that a mouse, too, would die in such a container. However, when Priestley put the plant and the mouse into the same container, they lived longer. This was some of the first evidence that green plants use carbon dioxide and give off oxygen.

PHOTOSYNTHESIS

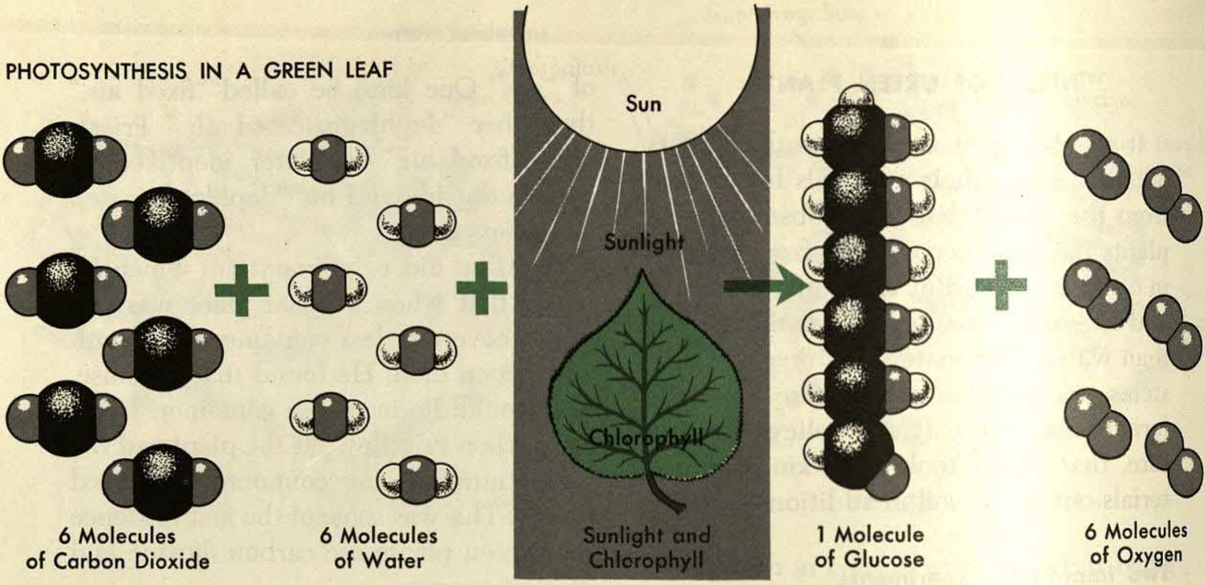
Today scientists know that green plants chemically build sugar from carbon dioxide and water. In order to do this work, energy is required. The visible radiant energy from the sun is used. Chlorophyll is the green material which makes it possible for plants to use radiant energy in this way. Because it is a chemical synthesis using light, the process is called ***photosynthesis.***

Glucose

One kind of sugar which plants make, ***glucose,*** has the chemical formula $C_6H_{12}O_6$. This formula represents one molecule of glucose. What elements make up the molecule? How many atoms of each are there in the molecule? The chemical equation for photosynthesis may be written as follows:

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} + \begin{matrix}\text{Energy From}\\ \text{Sunlight}\end{matrix} = \underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{O_2}$$

PHOTOSYNTHESIS IN A GREEN LEAF



From the equation on page 427, it seems that the energy of sunlight causes carbon dioxide and water to combine directly to form sugar. It is not all that simple. In fact, how it happens is not completely understood. But chemists know a great deal more about photosynthesis today than they did in Priestley's time.

Three Major Steps

In the past 200 years, discoveries made by many scientists have added greatly to our understanding of photosynthesis. There are at least three phases, or major steps, in the process. In the first phase, the energy from sunlight is used by chlorophyll to break down water into hydrogen atoms and oxygen atoms. The oxygen atoms combine to form molecules of oxygen and are given off as a byproduct. This first phase is the only one in which light is necessary as a source of energy.

In the second phase, the hydrogen atoms combine with carbon dioxide. This combination forms a compound that is something like sugar, but it has only three carbon atoms in its molecule.

In the third and last phase, this sugar-like compound is changed into a simple sugar, glucose, which, as the formula shows, has six carbon atoms in its molecule.

There are many different kinds of chemical reactions in the three phases. Not all of them are understood, but scientists hope they will be understood eventually.

Role of Enzymes

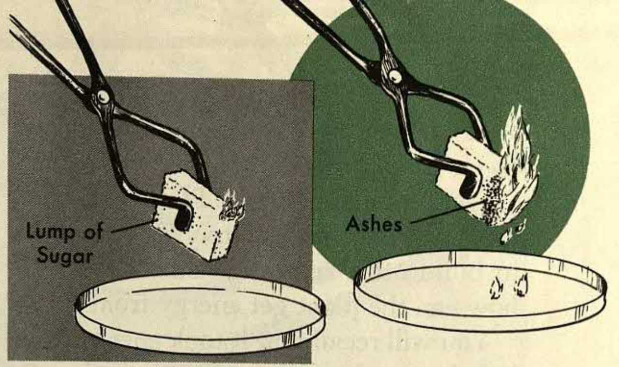
The chemical changes that the compounds carbon dioxide and water go through before their atoms become rearranged into sugar molecules take place in the protoplasm of cells containing chlorophyll. But protoplasm, in addition to chlorophyll, must have other substances to bring about the chemical changes rapidly enough to make any difference. These substances are called ***enzymes*** (EN-zymz). An enzyme is a substance that controls chemical reactions in living things. It does this by increasing the rate at which the reaction takes place.

You are probably acquainted with some of the digestive enzymes that bring about chemical changes in the food you eat. But it takes thousands of different enzymes in the protoplasm of living things to enable it to carry on its work.

Before chemists can completely understand the different chemical changes that take place in protoplasm, they must know what enzymes are involved. Then, too, they must know how each enzyme does its work. Only some of this information is available to scientists today. Here is an important field for scientists to investigate in the future.

Nature of Catalysts

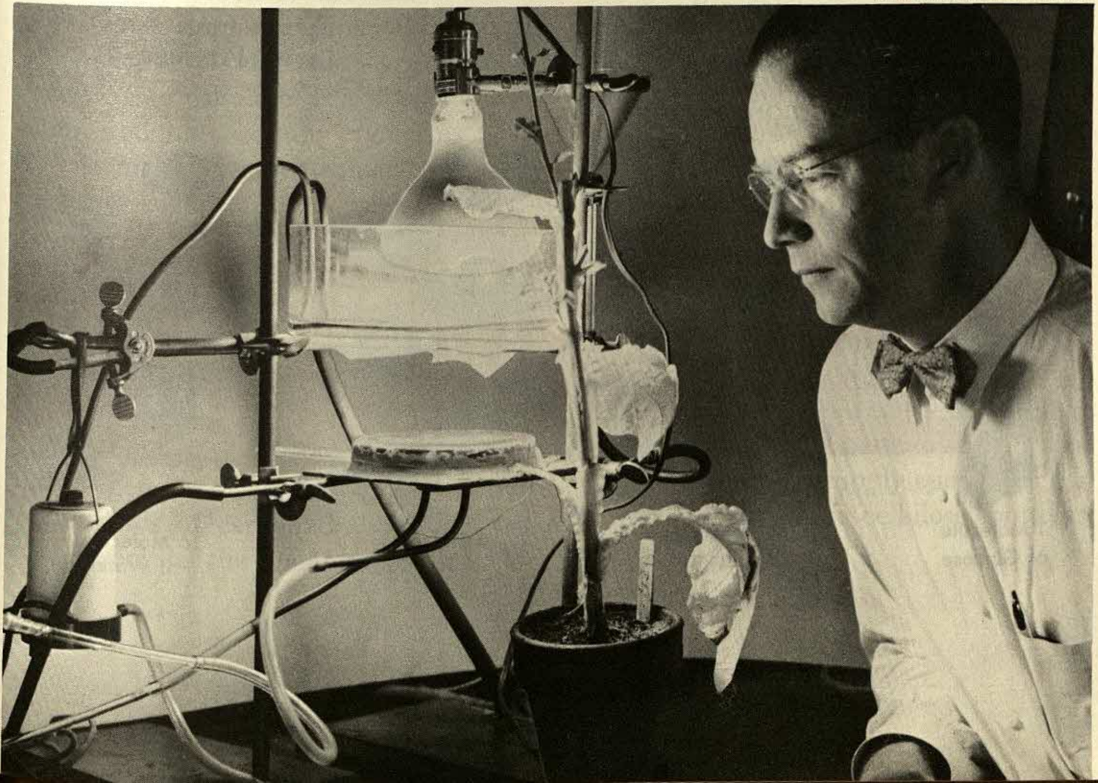
Enzymes are ***catalysts*** made by living things. A catalyst is any substance that changes the rate of chemical reaction.



You can show what a catalyst is in the following way. Obtain two lumps of sugar and a teaspoonful of cigarette ashes. With a piece of wire, or tongs, hold one of the lumps in a candle flame. Note its rate of burning. Rub the second lump of sugar in the ashes. You will note that the ashes make this second lump burn more rapidly. To put it another way, the ashes hasten the rate at which the sugar oxidizes. The ashes act as a catalyst in this chemical reaction.

Scientist observes a tobacco leaf in a special apparatus developed for measuring photosynthesis.

Brooklyn Botanic Garden



Releasing Energy From Sugar

So far, you have a general idea of how green plants use carbon, hydrogen, and oxygen to make sugar. Plant cells may use this sugar immediately for energy, or to build other important substances. But how can the plant get energy from sugar?

You will recall that it took energy (sunlight) to make carbon dioxide and water to form sugar. This energy is now bound up in each molecule of sugar. It is not yet being used to do work, but it's there. You will recall from Unit 2 that this type of energy is called potential energy. To change the potential energy in a sugar molecule to action energy, the molecule must be broken down. Just as the process of building up a sugar molecule involves a number of chemical changes, so does the breaking-down process. Protoplasm must have oxygen and the necessary enzymes to bring this about. The process can be summarized in one chemical equation as follows:

Compare this energy-releasing chemical equation with the energy-binding equation on page 427. Note that one is the reverse of the other. After the sugar molecule is broken down, the green plant can use the carbon dioxide and water to form another sugar molecule. Remember that this cannot take place without energy from sunlight. Protoplasm cannot use sunlight directly as energy. It must first be bound up in a sugar molecule and later released. Can you see why this is a better way to do this?

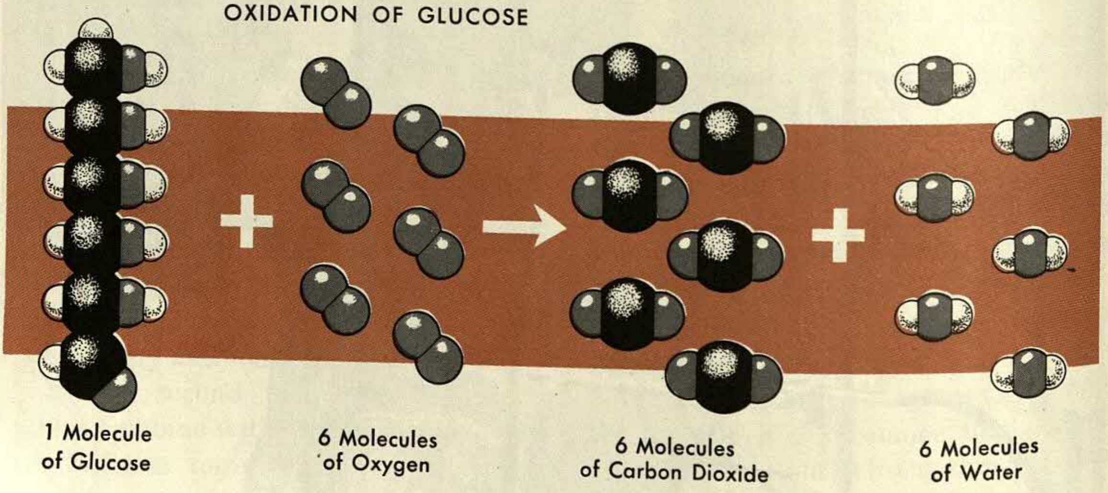
Sugar Molecules as Building Blocks

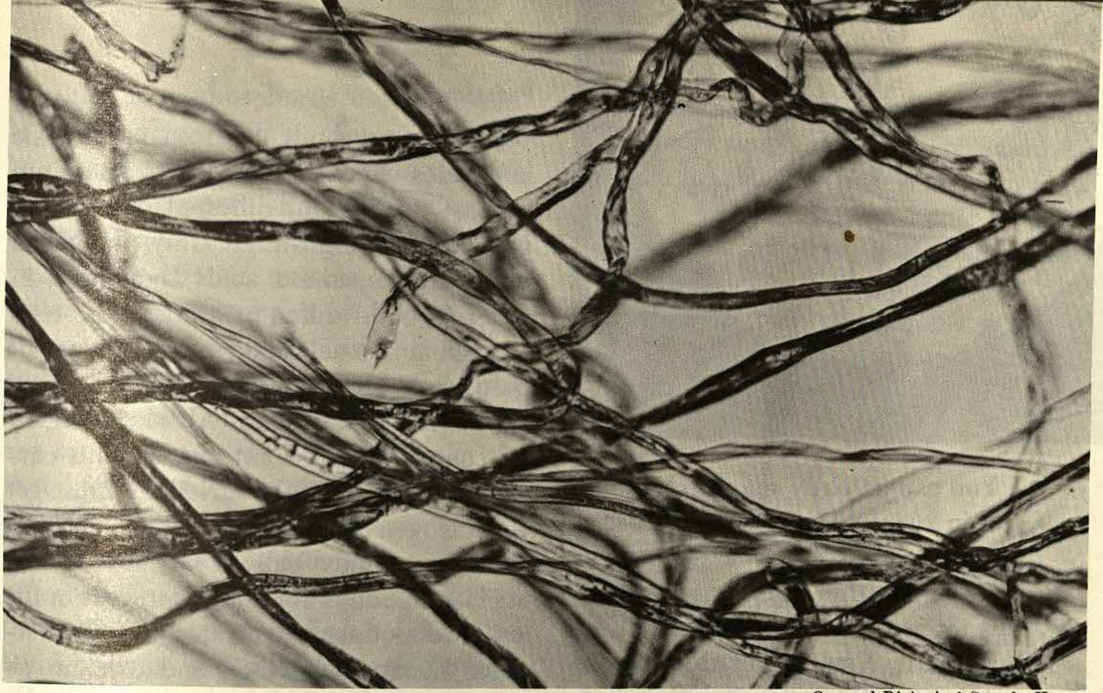
Sugar is important not only as a source of energy for plant cells. It is also the basic material out of which the protoplasm in cells makes all other materials.

There are a number of different kinds of sugar that are made from glucose. Molecules of starches, fats, proteins, enzymes, and vitamins are also made largely from glucose.

$$\underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} = \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6\,H_2O} + \begin{array}{l}\text{Energy for}\\ \text{Living Processes}\end{array}$$

OXIDATION OF GLUCOSE





General Biological Supply House

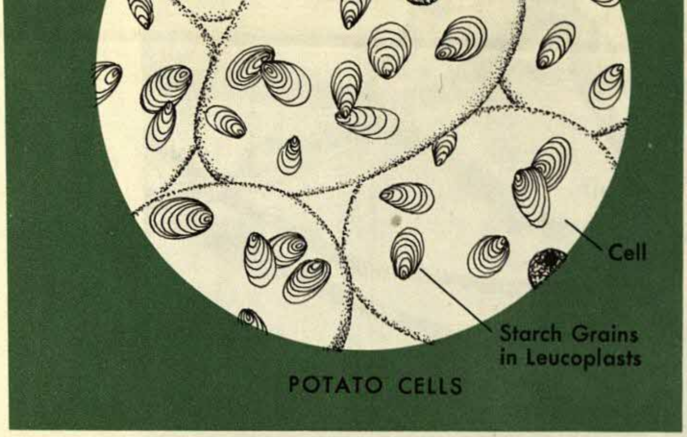
Cellulose of cotton, linen, and hemp plants is revealed in this microphotograph of these fibers.

The stiff, dry, straw-like material that is left after a plant dies is also made from glucose. It is called ***cellulose.*** All plant cells are encased in a cell wall made up of cellulose, which is the material that gives plants support. Much of the sugar which green plants make is eventually changed into cellulose. It is not soluble in water, and only certain organisms have the enzymes necessary to change cellulose back into sugar.

Carbohydrates

Starches, along with different kinds of sugars and cellulose, are called ***carbohydrates.*** Their molecules contain only atoms of carbon, hydrogen, and oxygen. No elements other than carbon, hydrogen, and oxygen are needed to make the different kinds of carbohydrates. All these are present in the sugar molecule. The number of atoms of each element and their arrangement in molecules are different in each kind of carbohydrate.

One way that sugar differs from starch is that sugar is soluble in water and starch is not. As you will see later, when materials in cells are dissolved in water, they may pass in and out of cells through cell membranes. When a plant cell changes some of its sugar into starch, it remains in the cell. Starch, then, can be stored more easily in cells than sugar. Whenever cells need sugar, they can change the starch back to sugar by the action of special enzymes. This is what one enzyme in your saliva does to some of the starch which you eat in bread or potatoes. When this happens in plants, the sugar can then be broken down to supply energy, or can be used to synthesize cellulose, proteins, or fats.



POTATO CELLS

You can actually see starch grains within the cells of a potato. Use a razor blade to slice a section of potato very thin. Unless you cut it this thin, you will not be able to see through it. Now mount this slice of potato on a slide, stain it with iodine, and put a cover slip over it. Examine the potato slice under a microscope. What do you see? How do you know? What would you think might be one possible use of the potato (tuber) to the whole potato plant?

Fats

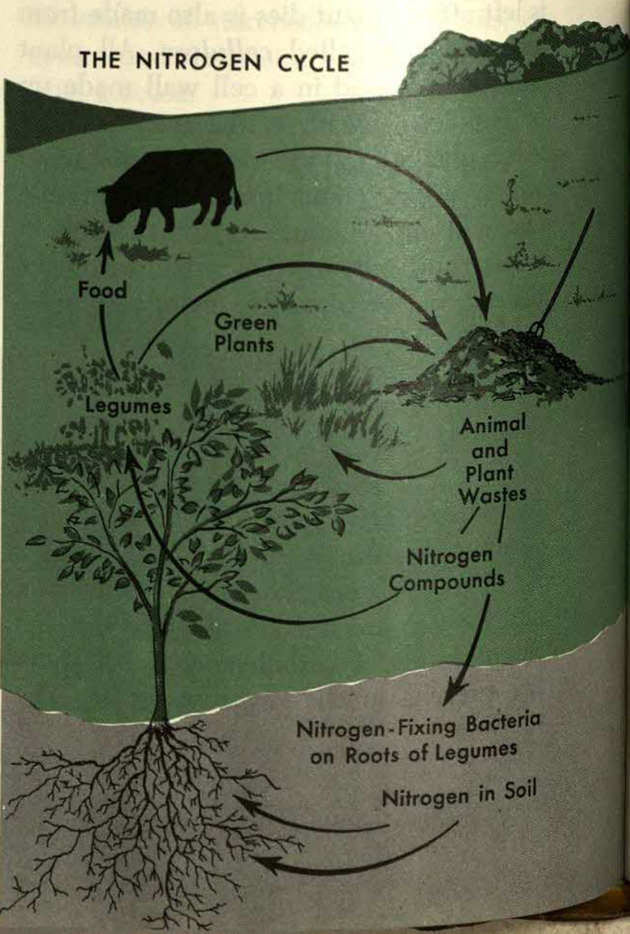
Fats, too, contain only carbon, hydrogen, and oxygen. The atoms of these elements in sugar are rearranged into molecules of fats through a number of different chemical steps. This rearrangement takes place in the protoplasm of plant cells. A number of different enzymes are needed to do the job. Fats may also be used as a source of energy. When this happens, they are changed back to sugar. By other chemical changes, they can be used for synthesizing proteins.

Fats are found in every cell. They are an important part of protoplasm and are needed by the protoplasm to do its work.

Proteins

Proteins are built up from more basic molecules called ***amino acids.*** There are at least twenty-four different ones in the proteins of living things. Only plants can make all the amino acids they need in order to build different kinds of protein.

Each amino acid molecule contains not only atoms of carbon, hydrogen, and oxygen, but also nitrogen. Although eighty percent of the air is nitrogen, plants cannot obtain it from the air. They must get the nitrogen for building amino acids from soil compounds called ***nitrates.*** Three such compounds commonly present in the soil are potassium nitrate (KNO_3), sodium nitrate ($NaNO_3$), and calcium nitrate ($Ca(NO_3)_2$). Some amino acids also contain sulfur and phosphorus. The atoms


THE NITROGEN CYCLE

of sulfur and phosphorus used in building molecules of amino acids must also be obtained from compounds in the soil.

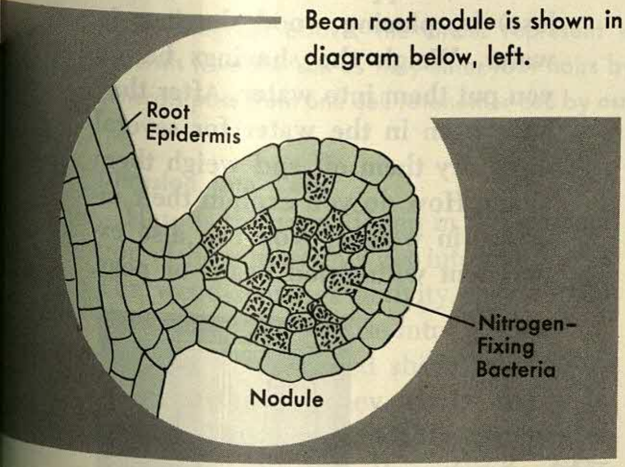
There is no part of the protoplasm of cells that does not contain proteins. Cell membranes contain proteins. Along with water, they make up most of the cytoplasm. The nucleoplasm is also largely composed of proteins. Enzymes and many other materials in cells are proteins. You can see why it might be tempting to say that life is made up of proteins. If you did, you would be almost right.

There are probably more than a million different kinds of proteins. About 500 of them have been identified by chemists. Some proteins have the largest, most complicated molecules of any known compounds. The hemoglobin in red blood cells is considered by chemists to be one of the more simple proteins. The empirical formula for this molecule is as follows:

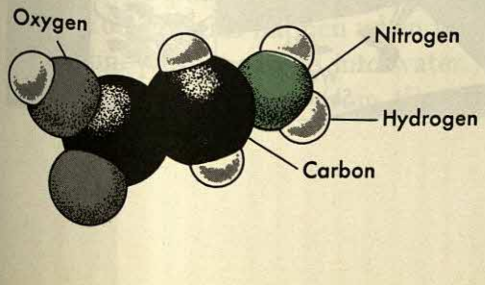
$$C_{3032}H_{4816}O_{872}S_{8}Fe_{4}.$$

What elements does it contain? How many atoms of each element does it contain? What is the total number of atoms in a hemoglobin molecule? How could you find the molecular weight of this molecule?

Bean root nodule is shown in diagram below, left.



Simplest amino acid, glycine, is diagrammed below.



PLANT NUTRITION

A visitor to Yosemite National Park in California must tilt his head way back to see the tops of sequoia trees towering 300 feet above him. How can the leaves of these trees, so far above the ground, obtain water and minerals from the soil? How can the huge roots, so far below the ground, obtain food from the leaves? Actually, the ways in which plants get materials from their environments have a certain basic similarity, whether they are microscopic water plants, buttercups, or great oak trees.

Movement of Molecules

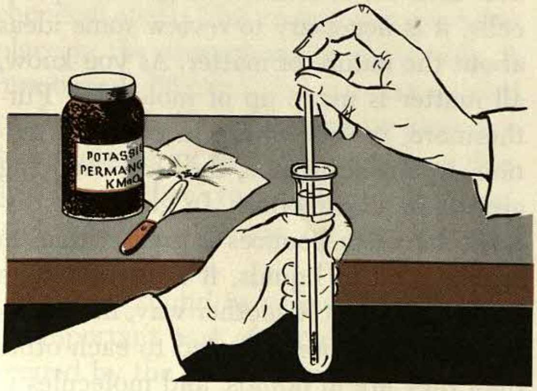
In order to understand how water, carbon dioxide, and minerals get into plant cells, it is necessary to review some ideas about the nature of matter. As you know, all matter is made up of molecules. Furthermore, molecules are in constant motion. In any substance, they are bouncing around in all directions. In gases, the distance between bounces is greater than in liquids, and in liquids, it is greater than in solids. To put it another way, molecules in solids are more attracted to each other than they are in liquids, and molecules in liquids are more attracted to each other than they are in gases. With these ideas in mind, you can take the first step toward understanding how materials get into plant cells.

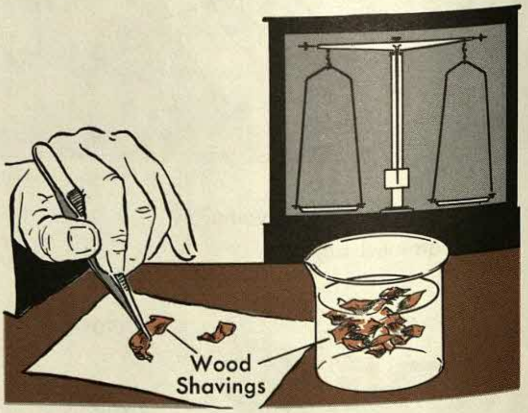
Diffusion of Molecules

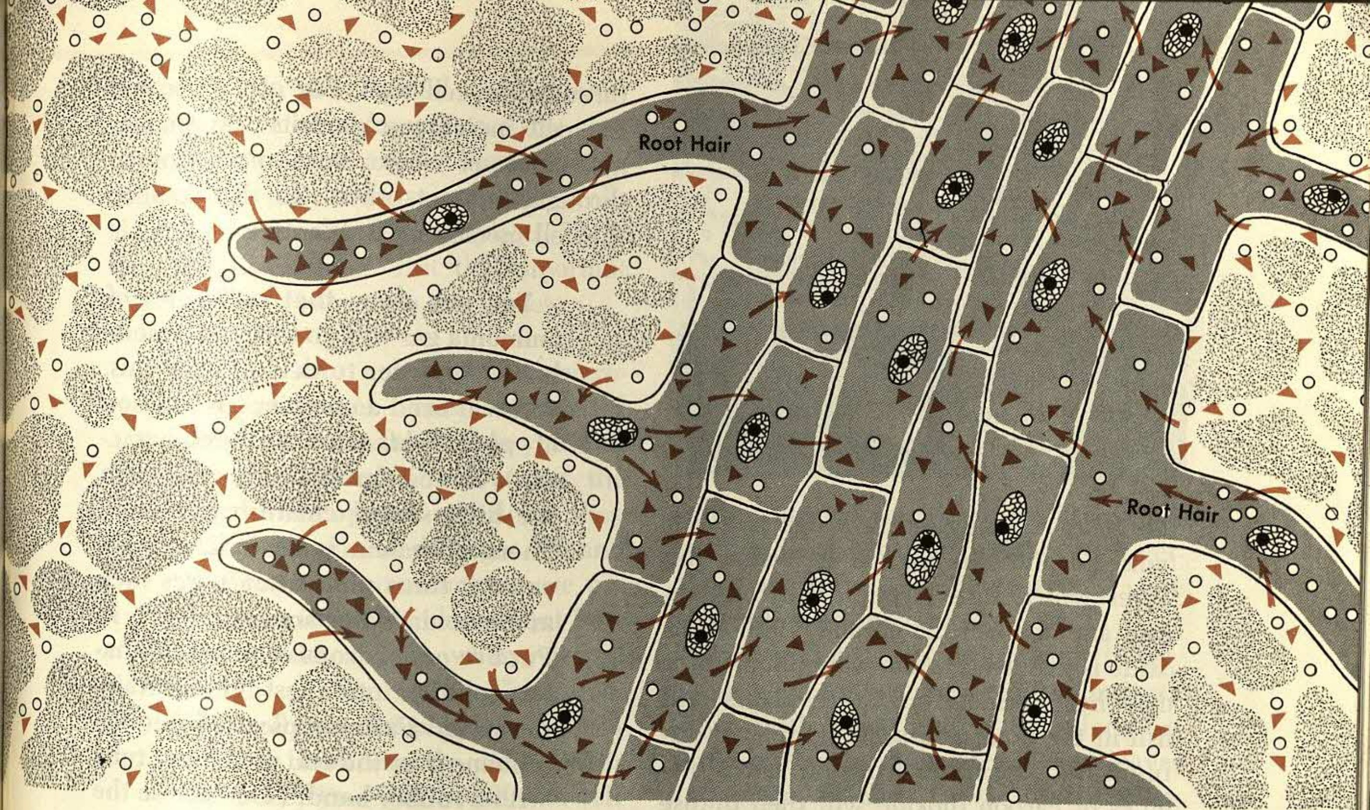
On page 339 in Unit 7, you were told to uncap a bottle of ammonia water three feet from your nose. You will find it helpful to repeat this activity. Shortly after you uncap the bottle, you'll smell the ammonia water. How can the molecular idea of matter be used to explain why it is possible to smell the ammonia water even though your nose is three feet from the bottle? As ammonia water molecules are bounced around inside the bottle, some of them are bounced into the air. Because air molecules are a gas, they are farther apart. There is now more space in which the ammonia water molecules can be bounced. They are bounced farther and farther away from the liquid until they reach your nose. The movement of molecules of one substance, such as ammonia water, through another substance, such as air, is called *diffusion*.

Here is something you can do to observe diffusion of molecules from a solid substance through a liquid. Put a few crystals of potassium permanganate into a section of glass tubing. Hold your finger over the top of the tubing as you put the other open end into a test tube filled with water. Push the tubing to the bottom of the test tube and remove your finger. As the molecules of purple potassium permanganate move out through the water, you can follow their purple trails. When molecules diffuse in this way through a liquid, they have gone into solution.

Molecules from some liquids will also diffuse into solids. You can show that this happens in wood (cellulose) by placing wood shavings in water. Weigh the shavings before you put them into water. After they have been in the water for several days, dry them off and weigh them again. How do you explain their increase in weight? You can also experiment with dried beans or peas.







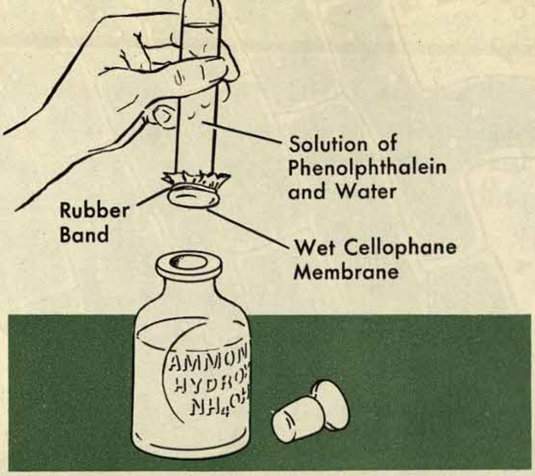
In the diagram above, the circles represent water molecules and triangles represent dissolved minerals from the soil as they enter root hairs by osmosis. From the root hairs, water and dissolved minerals pass from one cell to another cell by osmosis in the direction indicated by the arrows.

Diffusion into Cells

Here is the second step in the explanation of how materials get into plant cells. The wood-shavings activity showed that water molecules diffuse into cellulose.

If the water-logged shavings were exposed to the air, they would eventually dry out. This means that the water molecules may diffuse in the opposite direction when conditions change. They diffuse from a place where there are more of them to a place where there are less of them. You saw this happen when you put potassium permanganate into water. The molecules moved away from the tubing where there were more of them. Actually, the molecules are moving in both directions, but since more of them are moving out, the overall effect is of an outward movement. Have you ever been part of a small group trying to get through a classroom door when a large group inside was moving out? While the large group was coming out, some of you may have got into the room. However, many more were moving out than moving in.

The third step in the explanation is to show how these ideas apply to the way in which plant cells get the materials they need from their environment. First, apply



the ideas to a single-celled alga in a fish tank. Because the alga is in water, the water will diffuse through the cellulose wall and the cell membrane. Carbon dioxide is dissolved in the water. Some of it may have come from other plants and fish in the tank, and some may have diffused into the water from the air. Molecules of carbon dioxide will then diffuse through the cell wall and cell membrane into the cytoplasm of the cell. This will go on so long as there are more carbon dioxide molecules in the tank water than in the cell water. Minerals which the cell needs may also be dissolved in the tank water. Their molecules will also diffuse through the cell wall and membrane into the cytoplasm of the cell.

Selective Cell Membrane

There is a precaution which you must always keep in mind when you study science. The foregoing description of how materials get into a single-celled plant is only part of the entire explanation.

Some of the materials that are in the water cannot diffuse through the cell wall into the cytoplasm. The molecules of some of these materials are too large to pass through the cell wall. For other reasons, the cell membrane permits the smaller molecules of some substances to go through, but not others. In this respect, the cell membrane is selective.

You can show that molecules of ammonia gas will go through a membrane. In order to demonstrate this, you will need a one percent solution of *phenolphthalein* (fee-nohl-THAL-een). You can probably get this from the high school chemistry teacher. Phenolphthalein is an indicator because it turns pink when bases such as ammonia water are mixed with it. Put five or six drops of phenolphthalein solution into a test tube containing water. Fasten a piece of wet cellophane over the end of the test tube with a rubber band. (Do not use the kind of cellophane that is used to cover cigarette packs.) Now turn the test tube upside down and hold the membrane over a bottle of ammonia. How can you tell when molecules of ammonia have diffused through the membrane and formed ammonia water?

Leaf Cells

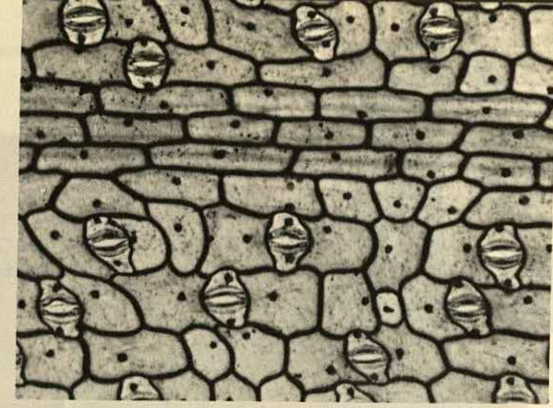
The cell layers of a leaf are put together something like a sandwich. The "bread" would be the upper and lower layers of cells which cover and protect the inner green layers. In some plants, the outer layers are coated with a waxy substance which helps to prevent the drying of the inner green layer.

The cells contain many small green bodies which contain chlorophyll. These bodies, which are carried in the cytoplasm, are called ***chloroplasts.*** Cells containing chloroplasts are the sugar-making cells of the plants. In some plants, cells along the stem contain chloroplasts. They, too, can make sugar. But the important sugar-making cells are in the leaves.

If you can get prepared microscope slides of cross sections of leaves, examine them. Can you find the chloroplasts? Observe that the cells do not appear exactly as they do in the diagrams on pages 400 and 426. Diagrams sometimes cause pupils to get incorrect ideas about how cells should appear when viewed through a microscope. Then, too, living cells are like people in that no two ever look exactly alike. With experience, you will be able to tell one kind of cell from another.

In leek leaves, which can usually be obtained in any vegetable store, you can observe these layers easily. Break the leek leaves with a sharp snap. Notice that you can pull off the surface layers, which are translucent and look a little like waxed paper. The inner layer is green and moist.

Although sugar-making occurs in the same way in the green cells of leaves and in the one-celled alga described on page 405, the matter of obtaining materials for this process is more complicated in the land plants. The simple alga had no problem about getting the materials it needed. There was water all around it. In the water were both carbon dioxide and minerals. It is believed that the first plants on earth could live only in water. It was not until some plants developed ways of getting water from the soil that they were able to live on the land.



General Biological Supply House

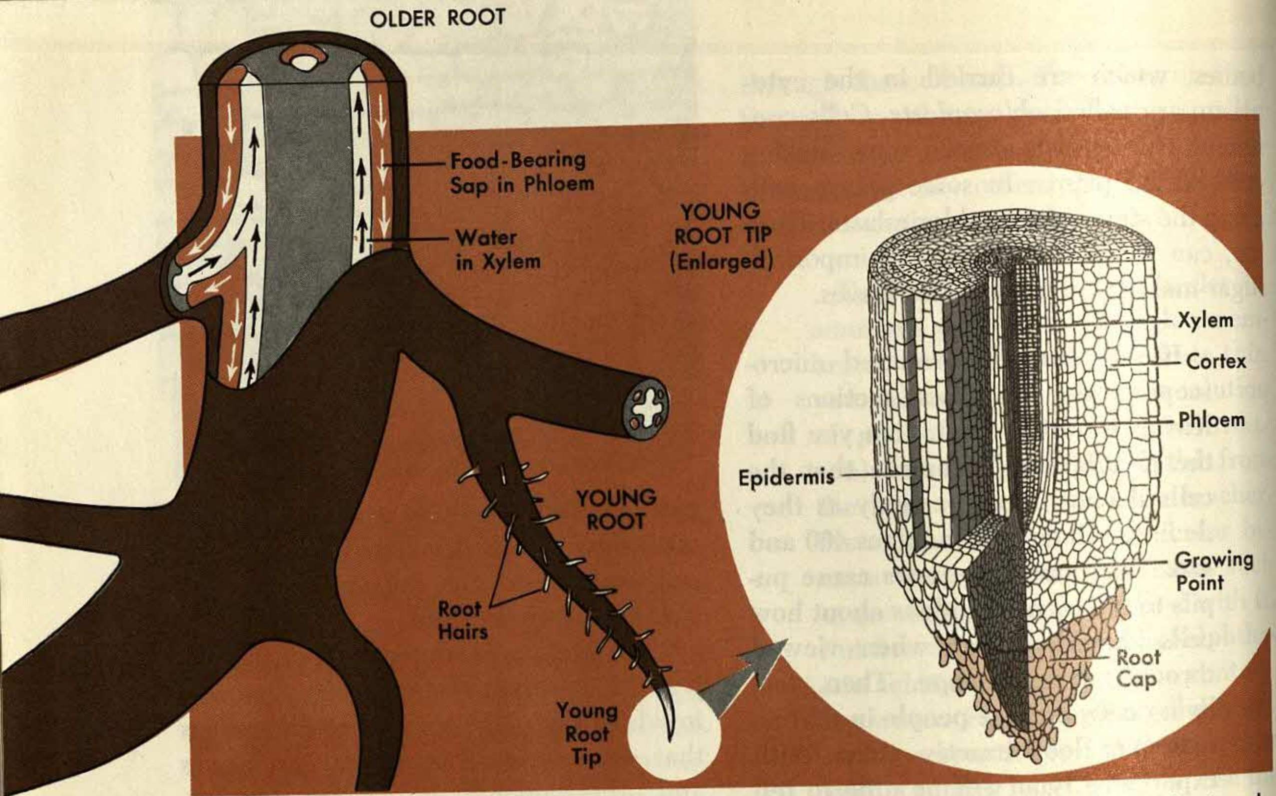
Cells and nuclei in epidermis of an onion.

Turn back to the description of the different plant groups on page 393. One way in which the plant groups are different is that some have roots, stems, and leaves and others do not. It was the development of roots, stems, and leaves that made it possible for plants to live on land. All three of these structures play important parts in getting water and minerals to the sugar-making cells of the plant.

Plant Roots

The roots of plants obtain water and minerals from the soil. In general, this is how they do it. Only the younger tips of roots actually do the job. The older parts support the plant and conduct water to the stem. Along the sides of young roots are very small projections called ***root hairs.***

As you can see in the diagram on page 438, each root hair is actually one cell. Between it and the water in the soil is only a cell wall. In this way, the root hair is like the alga cell in the tank of water.



Young roots (detail at right) are covered with root hairs through which water and dissolved minerals in soil enter water-conducting tubes of plant (see arrows). Older roots provide support to the plant and a conducting system of tubes through which water and food-bearing sap are transported.

Water and dissolved minerals diffuse from the soil in the same way that they did from the water in the tank into the alga cell.

These materials then diffuse from the root hair cell into the other root cells and finally into very small woody tubes, called ***xylem*** (ZY-l'm), which are bundled together. They extend from the roots through the stem and into the leaves. They are one kind of tube that makes up the ***veins*** in leaves. The diffusion of water into root hairs builds up a pressure that helps to force water up the xylem tubes to the leaves.

Here is a way in which you can grow seedlings so that you can observe root hairs. Line the inside of a test tube or beaker with wet blotting paper. Place several radish seeds between the blotting paper and the glass walls. You should also put just a little water in the bottom of the container to make sure that the blotting paper remains moist. After the radish seeds begin to grow, you can observe them with a magnifying glass. In a few days, you will see root hairs. They develop along the side of the root in back of the growing end.

Passage of Materials in Leaves

To complete the explanation of how water and minerals get to sugar-making cells in the leaf, refer back to the diagrammatic views of the leaf on page 426. The smaller arrows pointing outward from the xylem tubes in the diagram show that molecules of water diffuse from these tubes into the leaf cells. This keeps the cells inside of a leaf almost as wet as though they were in a tank of water. The protective layers of cells on the upper and lower sides keep much of this water from evaporating into the air.

As you will see, on the underside of the leaf the protective layer has openings called *stomata* (STOH-muh-tuh). These openings make it possible for air molecules to get to the cells inside the leaf. Among the air molecules are molecules of carbon dioxide, shown as brown dots in the diagram. They become dissolved in water inside the leaf and diffuse, along with it, into sugar-making cells. Now the cells have all they need to make sugar.

Stomata can be observed by stripping off the thin layer of cells covering the underside of a leaf of lettuce and examining it under a microscope. Tear the leaf toward the center. With forceps or tweezers, pull off the thin membrane. Lay a small piece of this on a microscope slide. Put a few drops of water, colored with iodine, on the slide. Compare stomata with diagram on page 426.

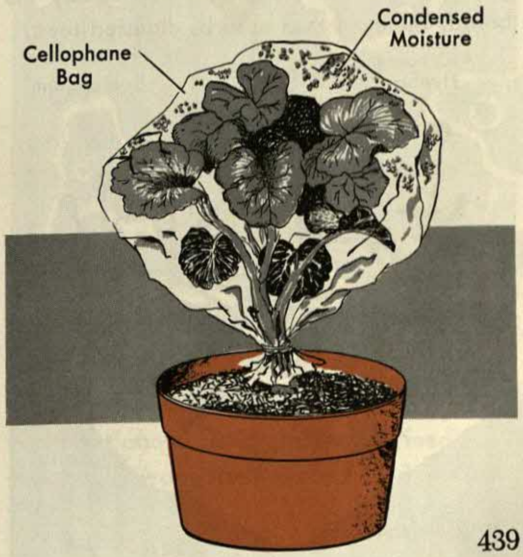
Transpiration

There is one more fact that is needed to explain how water gets up the xylem tubes. Water is constantly evaporating from leaves into the air. Much of it passes through the stomata when they are open during the daytime. The evaporation of water from plants is called ***transpiration*** (trans-pih-RAY-shun). See page 426.

As molecules of water are lost by transpiration, others replace them. The loss of water by transpiration, and the diffusion of water into root hairs, are two important processes that keep water moving up the very thin xylem tubes.

Transpiration from leaves can be demonstrated by tying a cellophane bag over a geranium plant, as shown in the diagram on this page. Where does the moisture, which condenses on the inside of the bag, come from?

You can use the same setup to do an experiment to find out if the water actually comes from the leaves. By covering each leaf with vaseline, you can prevent the evaporation of water from the leaves. How does the vaseline interfere with the process of transpiration?

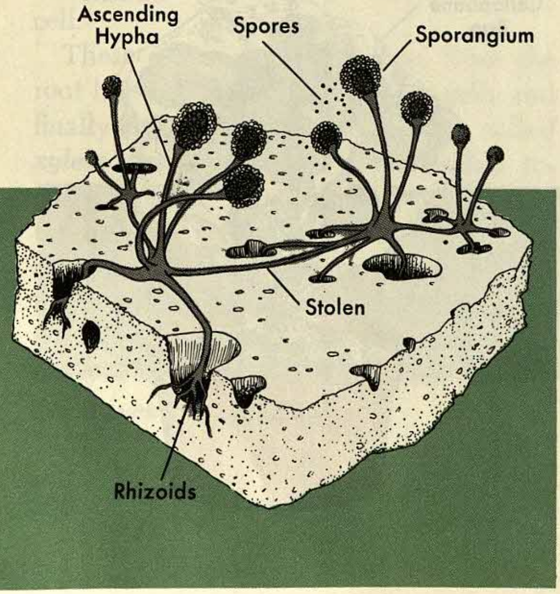


As you will recall, the sugar produced in a leaf cell may be used in the cell where it is produced, or transported to other cells. If it is to be transported to other cells, it diffuses out of the cell and into another set of tubes called the ***phloem*** (FLOH-em) tubes. These are the other tubes which make up the veins in leaves. They, too, are only one cell-wall thick. Water, and the materials dissolved in it, can easily diffuse in and out of the phloem tubes. Through these tubes, the sugar dissolved in water is carried to other plant cells. In these cells, the sugar may be used to supply energy, or changed into starch, cellulose, fats, vitamins or proteins.

NUTRITION FOR ANIMALS AND NON-GREEN PLANTS

Animals and non-green plants need carbohydrates, fats, proteins, water, and minerals. They need these materials for the same reasons that green plants do—to build protoplasm and supply energy. The big difference is that they cannot make sugar out of which they can build other carbohydrates and fats. Nor can they make the amino acids necessary for building proteins. They are dependent upon green plants for these materials. Many of them are also dependent upon plants for minerals and vitamins. They may get some of these materials from other animals, but those animals, in turn, get them from green plants.

Mold actually digests bread upon which it grows. It secretes enzymes, which liquefy the bread. The mold then absorbs digested food.



Material for Fungi

Bacteria, yeasts, and molds make up the group of non-green plants called fungi. It was explained in Problem 2 that, in order to propagate fungi, food had to be provided. Fungi of one kind or another will grow on living things and everything that was once alive—wood, leather, and many kinds of cloth. From these things they must get the materials which they need for growth.

Before these materials can be used, they must get inside the fungi cells. To do this, they must be able to diffuse through cell walls. In order to diffuse through cell walls, the materials, which are made up of large molecules, must be broken down into materials with smaller molecules. Here is an example. You may have seen mold growing on bread. Bread contains starch, but starch molecules are too large to diffuse into the cells of the bread mold. Before the bread mold can use the starch, its molecules must be broken down into smaller sugar molecules. An enzyme is needed, and mold produces the enzyme to do the job. The mold actually digests the starch in bread, but it is digested outside of the mold by enzymes secreted by the thread-like structures that go into the bread.

As you can see in the diagram on page 440, the digested food diffuses into the cells making up these threads. The food then diffuses from cell to cell throughout the mold. Molds do not have true roots, stems, or leaves.

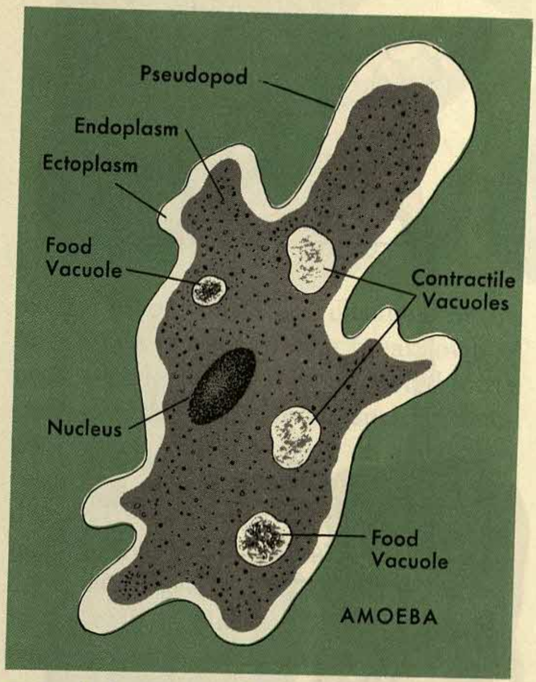
Materials for Amoebas

The single-celled animal shown on this page is an amoeba which lives in water, soil, and even in animals, including man. Through a microscope, these animals can be seen moving about in search of food, which consists mainly of one-celled animals and plants.

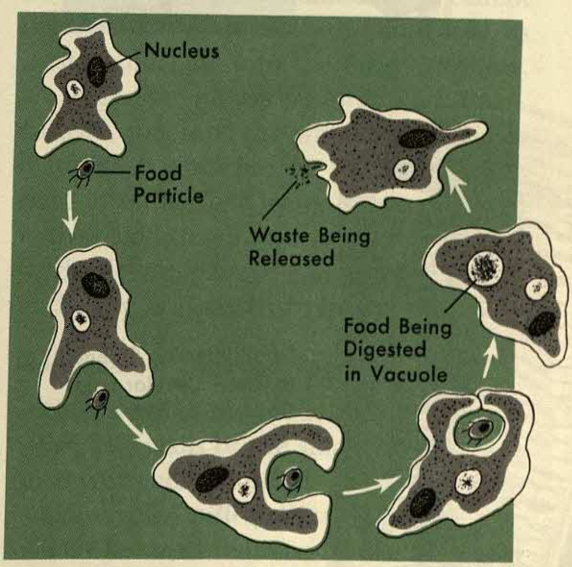
An amoeba moves about by extending its protoplasm in the form of a projection which looks like a foot. As it propels itself forward, the amoeba seems to stream into this false foot in a sort of flowing motion. The amoeba captures its food by engulfing it. The food, held in a cavity, or food vacuole, is then surrounded top and bottom by cytoplasm. The cytoplasm produces enzymes which break down, or digest, the food. The digested food then diffuses into the cytoplasm. The oxygen needed by the amoeba is dissolved in water and diffuses directly into the cell.

MORE COMPLICATED ANIMALS

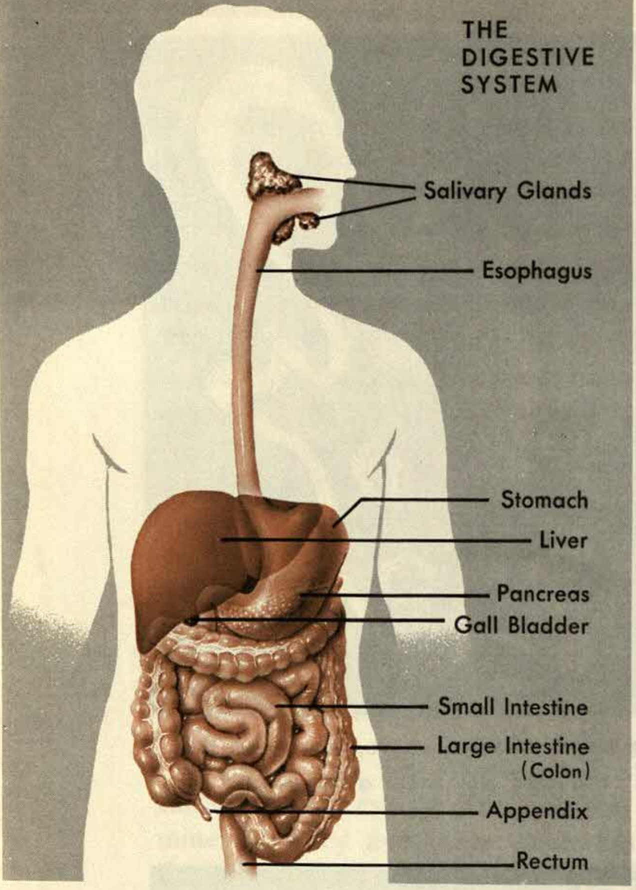
An amoeba is a protozoan. As you go from protozoa to chordata in the animal groups listed on pages 394–395, each appears to become more complicated than the previous one. One reason is that each has more cells than the previous one. The cells are located farther and farther from

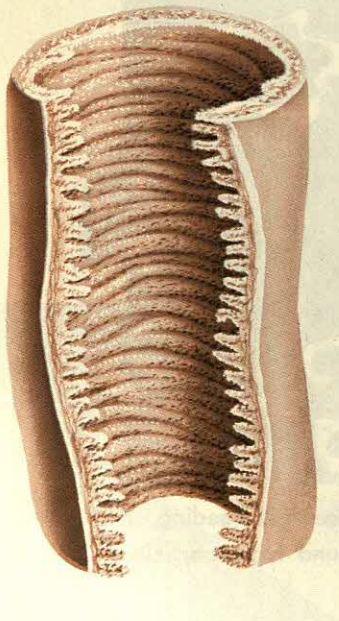


One-celled amoeba, above, is so small that it can be studied only under a microscope.



Amoeba, above, is in process of feeding. It practically wraps itself around food particles.





Small Intestine Opened to Show Circular Folds Covered by Villi

the sources of materials they need. In order to supply these cells, two things must be done. First, the food must be digested. Second, it must be transported to the cells, where it is needed. A study of man's body shows how this is done.

Man has, in common with many other animals, a food-carrying tube which passes through his body. The tube, called the ***alimentary canal,*** begins with the mouth and runs through to the lower end of the large intestine. Food digested in this canal enters the blood. Unused materials are eliminated.

Digestion in the Mouth

In the mouth, food is crushed into smaller pieces by the teeth. As the food is chewed, it is mixed with a digestive juice called ***saliva,*** produced by ***salivary glands.*** Glands are special organs in the body, producing chemical substances which aid in carrying on certain bodily activities. The saliva contains an enzyme which changes some of the large molecules of starchy foods, such as bread and potatoes, into smaller sugar molecules. Thorough chewing reduces food to smaller particles and assists this chemical action.

Chew a cracker slowly without swallowing any of it. After a while, you will notice that the cracker tastes sweeter than when you first put it into your mouth. What causes this to happen?

Digestion in the Stomach

After the food is swallowed, it is carried through a tube, the ***esophagus,*** into the stomach, which can hold about a quart. There are three layers of muscles in the stomach walls. When food is in the stomach, the combined action of the different muscle layers causes churning movements in the walls. By these movements, solid and liquid foods are mixed with the digestive juices in the stomach to form a thick liquid. The digestive juices are produced by millions of small glands in the walls of the stomach. These juices contain hydrochloric acid and enzymes that start the digestion of protein.

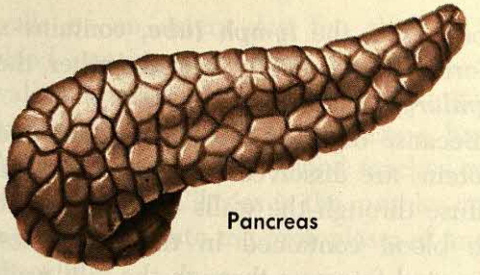
The work of breaking up the large protein molecules begins in the stomach, but it is not completed until the food passes into the small intestine. It may take from two to six hours for an entire meal to be liquefied and emptied from the stomach into the small intestine.

Digestion in the Small Intestine

The small intestine is a tube about one inch in diameter and about twenty feet long. Muscles in the walls of the small intestine produce a wave-like movement which keeps the food passing through.

As the partially digested food from the stomach passes through the small intestine, three different kinds of digestive juices are added to it. One is a digestive juice produced in the ***pancreas,*** a gland located near the stomach. The second is produced by glands in the walls of the intestine. The third juice, called ***bile,*** aids the action of enzymes in the other juices. Bile is produced by the liver and emptied into the small intestine through a tube.

Enzymes in these three juices complete the digestion of food in the small intestine. The molecules of starch which were not digested in the mouth, and the larger molecules of sugar, are changed into a simple type of sugar. The breakdown of protein molecules is also completed in the small intestine. Fatty foods, such as cream and butter, are not acted on until they reach the small intestine. There they are digested and broken down into simpler molecules which can be used by cells. All digested foods are now ready to be carried to the cells of the body. But what happens to undigested foods?



Elimination of Food Wastes

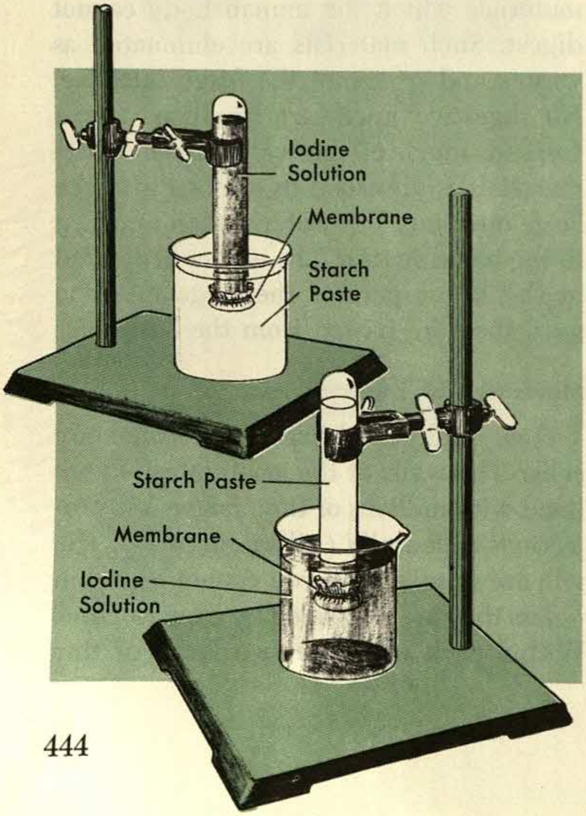
Many of the foods man eats contain materials which the human body cannot digest. Such materials are eliminated as wastes and pass into the ***large intestine.*** No digestive juices are produced there. Instead, much of the water in the waste materials is absorbed by the walls of the large intestine. The water is then returned to the blood stream. The wastes are stored in the lower part of the large intestine until they are passed from the body.

Movement of Digested Food

How do digested foods get to the body cells? The walls of the small intestine are lined with millions of tiny, finger-like projections called ***villi*** (***villus,*** singular). The villi are so small that you cannot see them unless they are magnified by a microscope. Within each villus are two kinds of tiny tubes. One, the ***lymph tube,*** contains a colorless fluid called lymph; the other, the ***capillary,*** contains blood.

Because digested starches, sugars, and proteins are dissolved in water, they can diffuse through the walls of the villi into the blood contained in the capillaries. Digested fats pass through the villi walls into the lymph, which is collected in larger tubes, or vessels, and later emptied into blood vessels.

If you can obtain a goldbeater's membrane, here is an experiment that you can do to show that starch will not diffuse through it, but that iodine will. Prepare an iodine solution by dissolving 10 grams of potassium iodide in 100 cc. of water. Then add 5 grams of iodine. This solution can be used to test for starch. It turns starch a blue-black color.



Pour the iodine solution into one test tube and fasten a piece of the goldbeater's membrane over the end of the tube with a rubber band. Turn the test tube upside down into a beaker containing a 1 percent starch paste. To make the starch paste, mix 1 gram of arrowroot starch in 10 cc. of cold water. Then pour this paste into 90 cc. of boiling water. Stir to make sure that it is free of lumps.

Prepare another test tube by putting starch paste into the test tube and covering it with a membrane. Put this tube into a beaker containing the iodine solution.

How can you tell if the starch diffuses through the membrane? How can you tell if the iodine diffuses through the membrane?

THE CIRCULATORY SYSTEM

A medium-sized person has from five to six quarts of blood in his body. All of it is contained in a closed system of tubes called ***blood vessels.*** Unless the walls of the blood vessels are cut or broken open, blood never flows outside of them. A black-and-blue mark resulting from a blow on the body is caused by blood which has escaped from damaged blood vessels. The blood vessels, blood, and the heart make up the ***circulatory system.***

Blood contains a number of different substances, which make it able to do many things. The liquid portion, called ***plasma,*** is mostly water, and makes up more than ninety percent of the blood. The blood also contains red blood cells, white blood cells, and small disc-shaped bodies called platelets.

The Heart as a Pump

The heart is really two pumps in one. The left side makes up one pump and the right side the other. The wall of the heart is made up of muscles, as you can see in the diagram opposite page 488. Blood is forced from the heart into the blood vessels by the contraction and expansion of these muscles. Each time this action occurs, the heart is said to beat.

Food Delivery by Blood

Blood can circulate through the body in less than a minute. Not very long after food enters the blood in the villi, it is delivered to cells of the body.

You can trace the passage of sugar from the small intestine to a muscle cell in the right arm of an active person. The sugar diffuses into the blood while it is flowing through capillaries in the villi of the small intestine. From the very small vessels of the capillaries, it flows into a larger blood vessel called a vein. A vein is the vessel that carries blood to the heart. Before sugar can be stored, however, it must pass through the liver and be changed into an animal starch called ***glycogen.*** From the liver, the blood now moves through other veins to the heart.

The blood, pumped to the lungs through chambers on the right side of the heart, returns to chambers on the left side of the heart. It is then pumped out of the heart through blood vessels called ***arteries,*** which extend to every part of the body. Some of the sugar which you started to trace from the villi is now pumped with blood through an artery in the right arm.

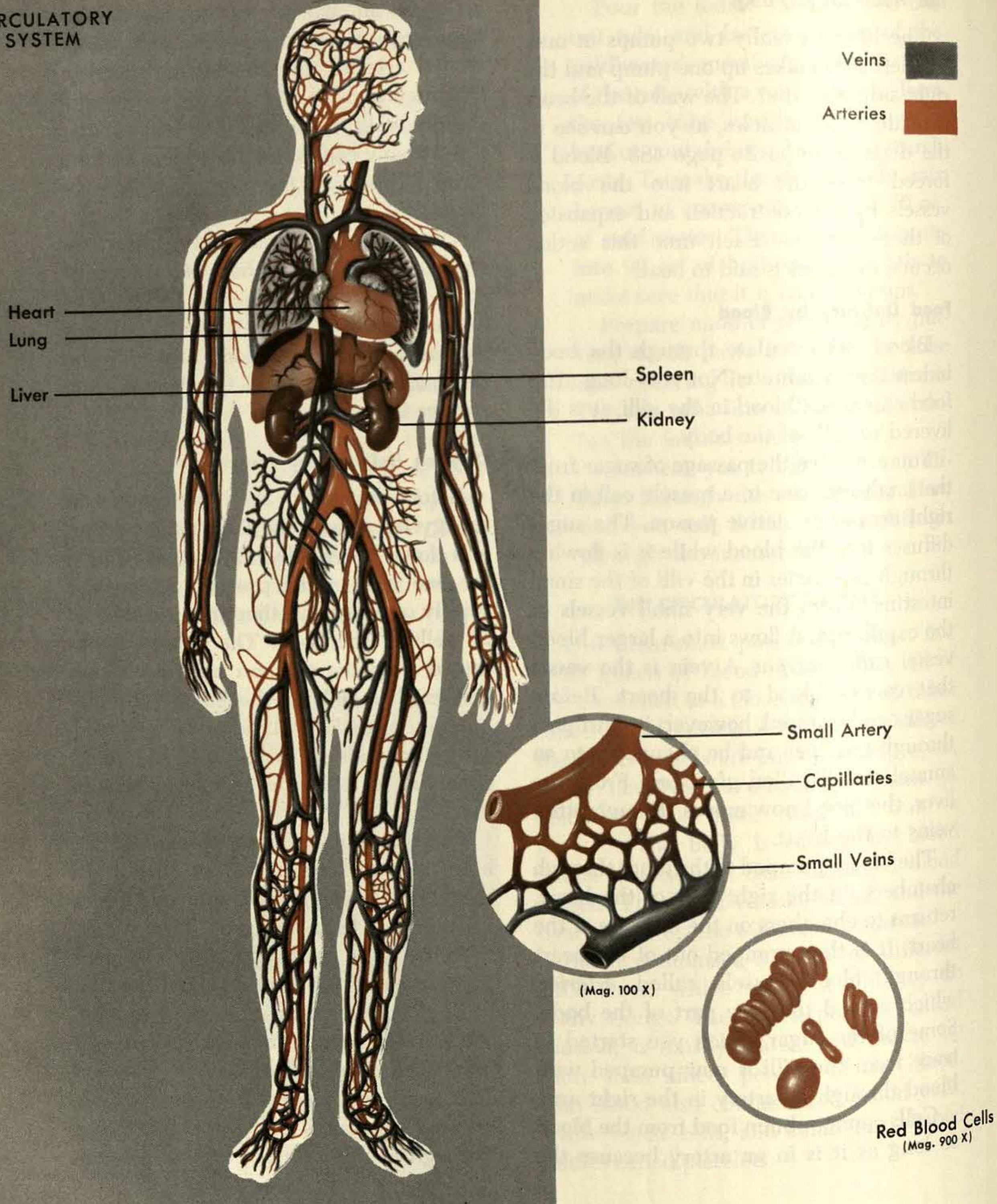
Cells cannot obtain food from the blood so long as it is in an artery because the walls of an artery are too thick. The blood continues to flow through thick-walled arteries into smaller and smaller arteries which, in the muscle tissue, have thinner walls. Soon the blood reaches one of the many capillaries in the muscles and sugar diffuses into the protoplasm of muscle cells.

The blood, in the same way, transports food to all cells of the body. Certain cells store surplus food, either in the form of animal starch, or as fat. When there is not sufficient food in the blood to supply the demands of cells, food is released from storage in the cells.

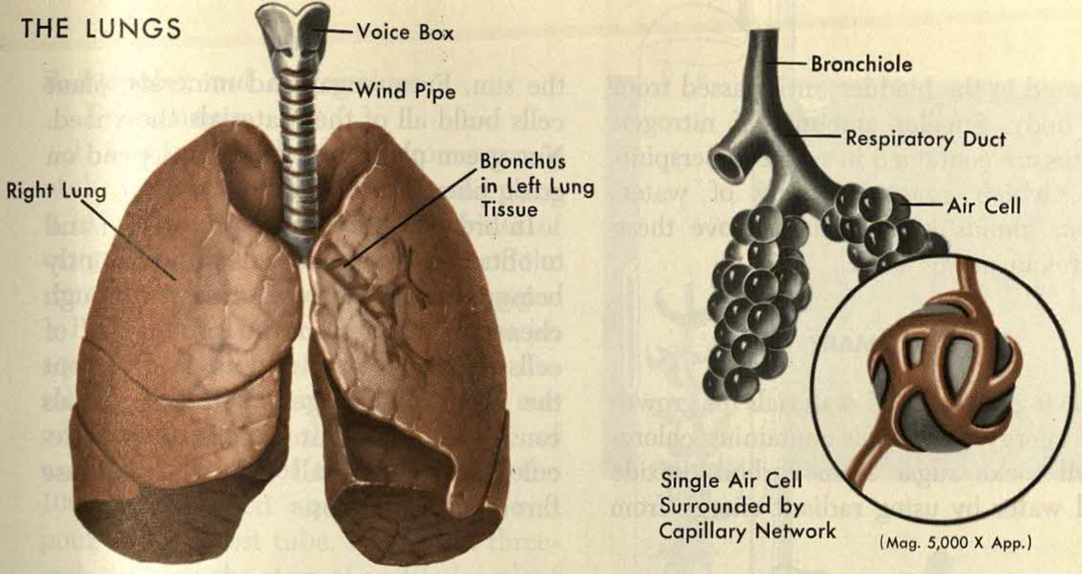
Oxygen Delivery by Blood

Before the cells of the body can obtain energy from food, the food must be broken down chemically. Oxygen is needed for one part of the process. A constant supply of oxygen is, therefore, needed by all cells of the body. The oxygen is obtained from the air man breathes and is delivered to cells by the blood. The diagram on page 447 will help you to understand how air is taken into the lungs through the windpipe and forced out of the lungs.

There are millions of tiny air sacs in the lungs. After blood enters the heart from the body, it is pumped into capillaries surrounding these air sacs. The oxygen from the air in the lungs diffuses through the thin walls of the air sacs and the thin walls of the capillaries into the blood. There the oxygen combines with a substance called hemoglobin in the red blood cells, or ***corpuscles,*** and is carried by them to other capillaries throughout the body. Through capillary walls, the oxygen dif-



CIRCULATORY SYSTEM



Human lungs, left; cluster of air sacs, center; and greatly enlarged view of air sacs at right.

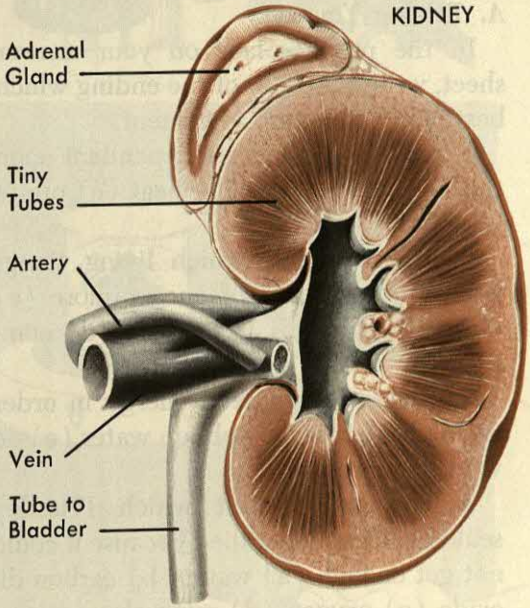
fuses into the lymph that surrounds all cells and finally diffuses into the cells.

Waste Removal From Cells

When sugar is used by cells, water and carbon dioxide are given off as waste products. Other wastes which contain nitrogen are also given off by cells as the protoplasm is worn out and as protein foods are used to produce energy. All these wastes must be carried away if the cells are to operate properly. The blood also removes these waste materials.

The wastes diffuse from the cells through small veins, which lead into larger veins, until the blood with wastes is returned to the heart. One of the heart chambers pumps the blood into capillaries surrounding air sacs in the lungs. Here the carbon dioxide and some water diffuse from the blood into the air sacs of the lungs and are breathed out.

Nitrogen wastes are removed from the blood as it is pumped through blood vessels in the kidneys. The wastes are collected in tubes as ***urine,*** and the urine



There are two kidneys in the upper abdominal cavity. They help remove nitrogen wastes.

is stored in the bladder until passed from the body. Smaller amounts of nitrogen wastes are contained in sweat or perspiration, which consists largely of water. ***Sweat glands*** in the skin remove these wastes in perspiration.

SUMMARY

Living things need materials for growth and energy. Plant cells containing chlorophyll make sugar from carbon dioxide and water by using radiant energy from the sun. From sugar and minerals, plant cells build all of the materials they need. Non-green plants and animals depend on green plants for needed materials.

In order to build more protoplasm and to obtain energy, materials are constantly being built up and broken down through chemical changes in the protoplasm of cells. Enzymes are used to bring about the chemical changes. Before materials can move in and out of cells, their molecules must be small enough to diffuse through membranes.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. All living things are dependent upon the sun for (a) light (b) heat (c) protoplasm (d) energy.

2. The materials which living things need are composed of one or more (a) elements (b) cells (c) plants (d) compounds.

3. Living things need energy in order to (a) have food (b) obtain water (c) do work (d) breathe.

4. The green plant which Priestley sealed in a container died because it could not get enough (a) water (b) carbon dioxide (c) oxygen (d) minerals.

5. In making sugar, plants use the energy from sunlight in (a) obtaining water from the soil (b) breaking down water into hydrogen and oxygen (c) combining carbon dioxide and water (d) breaking down carbon dioxide into carbon and oxygen.

6. The chemical reactions in protoplasm are controlled by (a) the sun (b) chlorophyll (c) enzymes (d) diffusion.

7. The protoplasm of cells is made up largely of (a) proteins (b) fats (c) sugar (d) starch.

8. Materials diffuse into and out of cells because (a) of the elements they contain (b) they will not dissolve in water (c) they are gases (d) of their molecular action.

9. It is believed that the first plants on earth (a) were fungi (b) lived in water (c) had roots, stems, and leaves (d) were ferns.

10. Before much of the food that animals eat can get into their cells, it has to be (a) changed to sugar (b) digested (c) dried (d) changed to larger molecules.

B. Planning and Performing Experiments

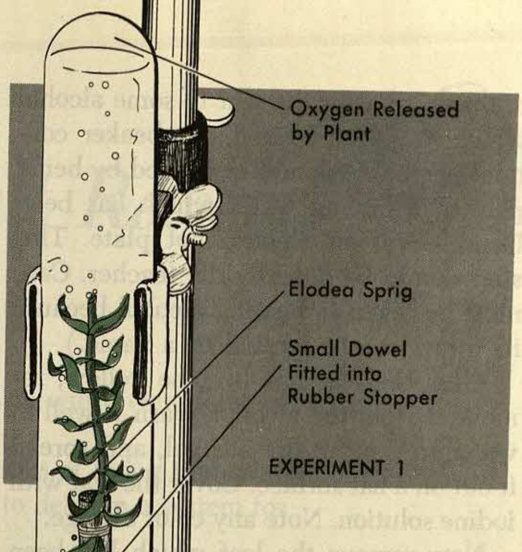
1. Cut one of the stems from a sprig of the water plant called Elodea and place it in water. You can observe bubbles of oxygen coming from the cut end of the stem when the leaves are making sugar.

Boil about 100 cc. of water from an aquarium to drive off gases that are dissolved in the water. Then dissolve one gram of sodium bicarbonate in 250 cc. of water. Add 2 cc. of this solution to the 100 cc. of boiled aquarium water and pour it into a test tube. Now cut a three-inch tip from the stem of an Elodea plant and fasten it to a stick as shown in the diagram. Place it tip down in the tube.

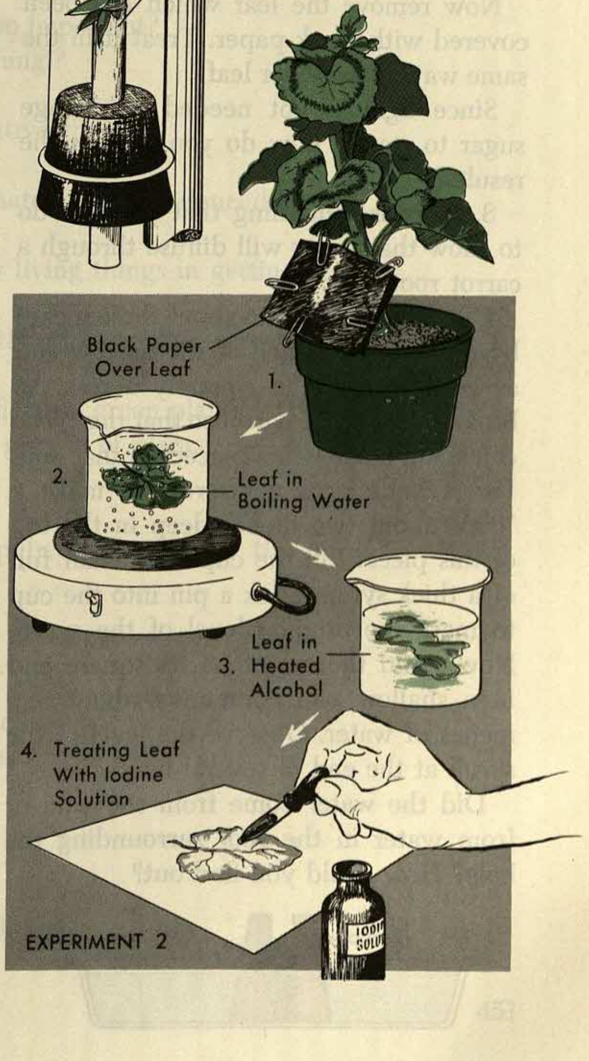
Observe the bubbles coming from the cut end when the test tube is placed in the sun. The rate of oxygen-bubble release indicates the rate at which photosynthesis is taking place. Plan experiments which use this setup to compare the rate of photosynthesis in different intensities of light.

2. You can do an experiment to find out whether more starch is formed in leaves in daylight or in darkness. You will need a potted geranium plant, water, iodine solution (see page 444 for preparation), rubbing alcohol, a heat source such as an electric hot plate, two beakers, black paper, and paper clips.

Carefully cover one of the geranium leaves with black paper. Make sure that no light gets to the leaf. Hold the paper in place with paper clips. Allow the plant to remain in the light for two days. Remove one of the leaves that has been exposed to the light and place it in water heated to the boiling point. After two


Oxygen Released by Plant
Elodea Sprig
Small Dowel Fitted into Rubber Stopper

EXPERIMENT 1



EXPERIMENT 2

minutes, transfer the leaf to some alcohol which has been heated. (A beaker containing alcohol should be heated by being placed in boiling water which has been heated over an electric hot plate. This step should be done by the teacher. Care must be taken in heating alcohol because its fumes can be ignited by a flame.)

After the leaf has become yellow, remove it from the alcohol, wash it well in water to remove the alcohol, and spread it out on a flat surface. Cover the leaf with iodine solution. Note any color change.

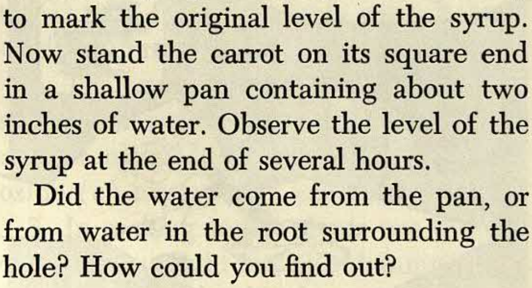
Now remove the leaf which has been covered with black paper. Treat it in the same way as the other leaf.

Since light is not needed to change sugar to starch, how do you explain the results?

3. Here is something that you can do to show that water will diffuse through a carrot root.

Cut a carrot down to about three inches by removing as much of the narrow end as is necessary. Cut squarely across the broader end of the carrot so that this piece can stand alone when placed on that end. Use a knife or a corkscrew to make a "cup" about two inches deep in the top of this piece. Fill the cup about half full of a thick syrup. Stick a pin into the cup to mark the original level of the syrup. Now stand the carrot on its square end in a shallow pan containing about two inches of water. Observe the level of the syrup at the end of several hours.

Did the water come from the pan, or from water in the root surrounding the hole? How could you find out?



C. Examining the Organs of a Chicken

Chickens and other fowl swallow their food whole and store it temporarily in a structure called the ***crop.*** The food then passes into one stomach, where it is mixed with digestive juices. It then goes into another heavily muscled stomach, which grinds and crushes it. Digestion is completed in the small intestine. Liver, heart, and lungs are other organs that are important in supplying the chicken cells with materials they need.

If you know of someone who cleans or dresses chickens, have them save these organs for examination by your class. The organs must be examined as soon as possible after removal from the chicken.

1. Trace the chicken's alimentary canal from the crop through the intestine. With a sharp knife, open each organ and examine it.

2. How does the liver compare in size with the other organs?

3. Find the gall bladder. Why must it be removed carefully before the liver is used for food?

4. Find the blood vessels that join the heart with the lungs. Compare the texture of the lungs with the heart. Why is it so different in the two organs?

D. Preparing Reports

Prepare reports on the ways in which the animals listed below obtain and prepare food for use by their body cells. Use biology books and encyclopedias to obtain this information. You may also want to draw diagrams to help you compare the organs of these different animals.

(1) planarian (2) earthworm (3) frog
(4) fish (5) cow

Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the more important ideas in this unit.

1. What are four important characteristics of living things?
2. Why was it necessary for biologists to develop a system for classifying living things?
3. Why are the cells of living things so important?
4. What must be done to propagate fungi?
5. How do flowers produce seeds?
6. Why are plants propagated vegetatively?
7. How do green plants make sugar?
8. Why is sugar considered a basic material which is needed by all living things?
9. In what ways are enzymes used by living things in getting the materials they need?
10. What makes it possible for such things as water, carbon dioxide, sugar, and minerals to diffuse?
11. In what ways is transpiration beneficial to green plants?
12. Why are minerals important to the growth of plants?

B. WORDS IN SCIENCE

Write in one sentence the relationship between each of the following pairs of words or phrases:

1. genus—species
2. algae—fungi
3. plants and animals—cells
4. cytoplasm—nucleoplasm
5. cells—fission
6. chlorophyll—sugar
7. stamen—pistil
8. seed—germination
9. radiant energy—greenhouse

10. spawn—milt
11. molecules—diffusion
12. photosynthesis—enzymes
13. sugar—cellulose
14. proteins—mineral elements
15. xylem—phloem
16. glands—digestion
17. capillaries—diffusion
18. hemoglobin—oxygen
19. vaccination—antibodies

You Can Go Further

A. By Working with Plants and Animals

1. You can do experiments with white rats to find out how diets lacking certain vitamins affect their growth. The General Biological Supply Company in Chicago will send you instructions on how to do an experiment with diets lacking vitamin D. You can obtain diets lacking other vitamins and minerals from Nutritional Biochemicals Corp., Cleveland 28, Ohio. If you are interested in doing dietary experiments, write to them for additional information.

2. Make a collection of insects found in your neighborhood and prepare a description of the life history of each. A book of great help in such a project is *Insects* by Herbert S. Zim and Clarence Cottam, published in 1951 by Simon and Schuster, New York, N.Y.

B. By Reading

Aistrop, Jack. *Enjoying Nature's Marvels.* New York: The Vanguard Press, 1961.

Describes mammals that fly, birds that do not, and so on.

Bonner, John Tyler. *Cells and Societies.* Princeton, N.J.: Princeton University Press, 1955.

Discusses sameness and diversity in living society.

Christensen, Clyde M. *The Molds and Man.* Minneapolis: University of Minnesota Press, 1951.

Treats fungi thoroughly.

Cosgrove, Margaret. *Strange World of Animal Senses.* New York: Dodd, Mead and Company, 1961.

Explains development of senses in various animal groups.

Dawson, E. Yale. *How to Know the Seaweeds.* Dubuque, Iowa: William C. Brown Company, 1956.

An illustrated manual for identifying marine algae of the Atlantic and Pacific coasts.

Gray, James. *How Animals Move.* New York: Cambridge University Press, 1953.

Describes biological, physical, and mechanical principles of movement and locomotion in animals.

Hoffman, Joseph G. *The Life and Death of Cells.* New York: Doubleday and Company, 1957.

Tells what modern science knows about the living processes and fundamental units of life.

Hyde, Margaret O. *Animal Clocks and Compasses.* New York: Whittlesey House, 1961.

Describes fascinating natural rhythm by which fish, insects, and other animals live and travel.

Lane, Frank W. *Animal Wonder World.* New York: Fawcett Publications (Premier Books), 1957.

Interesting sidelights on animal behavior.

Mason, George T. *Animal Baggage.* New York: William Morrow and Company, 1961.

Describes curious ways in which animals carry their food, young, and nesting materials.

Pettil, Ted. S. *Animal Signs and Signals.* Garden City, N.Y.: Doubleday Books for Young Readers, 1961.

Tells how animals communicate with each other and man.

Prescott, Gerald W. *How to Know the Fresh-Water Algae.* Dubuque, Iowa: William C. Brown Company, 1954.

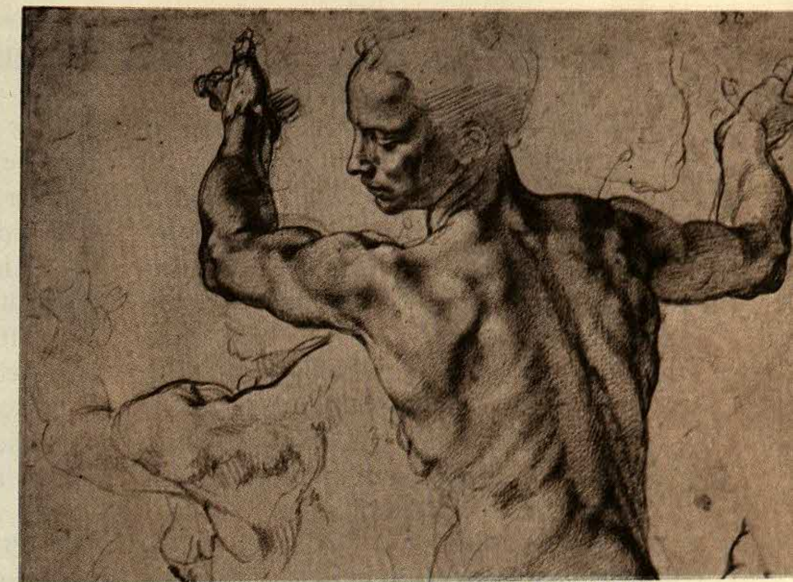
Provides drawings and keys to serve as guides in identifying the fresh-water algae.

Rand, Herbert W. *The Chordate.* New York: Blakiston Company, Inc., 1950.

Covers developmental and comparative anatomy of chordates, along with pertinent embryology.

Max Tharpe from Monkmeyer

UNIT 9



(Detail) Metropolitan Museum of Art
—Purchase 1924 Joseph Pulitzer Bequest

Human Beings

Human beings are the most complicated phenomena on earth. Rockets, satellites, television, and atomic energy are simple compared to a human being. It isn't that scientists have not been trying to find out all they can about human beings. Many scientists are studying them constantly.

The human ***anatomist*** studies the body to find out what its parts are and how they are put together. The human ***physiologist***, through experimentation, learns much about how the body carries on its different functions. The ***immunologist*** discovers some of the ways in which the body protects itself from disease. ***Psychologists*** study human behavior. These and other specialists in the study of human beings collect many facts about them. From these facts, they develop theories to explain the facts. It is only as theories are developed about the nature of human beings and the way they behave that scientists who study them are able to explain them. Some theories have been developed, but others are needed before scientists can satisfactorily explain a human being.

PROBLEM 1: WHAT IS THE HUMAN BODY?

There are many ways of describing the human body. You can do it by naming its parts and telling where each is located. You can describe it more completely by explaining what each part does. You can also describe it by comparing it to some other living thing.

Try to describe your body by naming its parts from top to bottom. You can do this quickly by naming the head, neck, trunk, arms, and legs. But each of these parts is made up of still others.

Your eyes, ears, nose, mouth, skull, and brain are parts of your head. The iris, retina, and several other parts make up your eyes. The iris of your eye is made up of still other parts such as muscles and nerves, and, finally, muscles and nerves are made up of cells. You are back again to the idea that all living things are made up of one or more cells.

CELLS

The one-celled amoeba is a complete living unit, or organism. It searches for food, digests it, and uses it for energy, growth, and repair. The amoeba also reproduces itself. Like other one-celled organisms, it's on its own, so to speak, and makes out very well.

The human body is made up of millions upon millions of cells. Like the amoeba, each of these cells must have food for energy and repair. Some body cells are growing and some are dividing to produce other cells like themselves. However, none of the cells making up the human body is a complete organism. None can live by itself as the amoeba can. Every body cell must be associated with other body cells in order to carry on. Living together, they make up a many-celled organism.

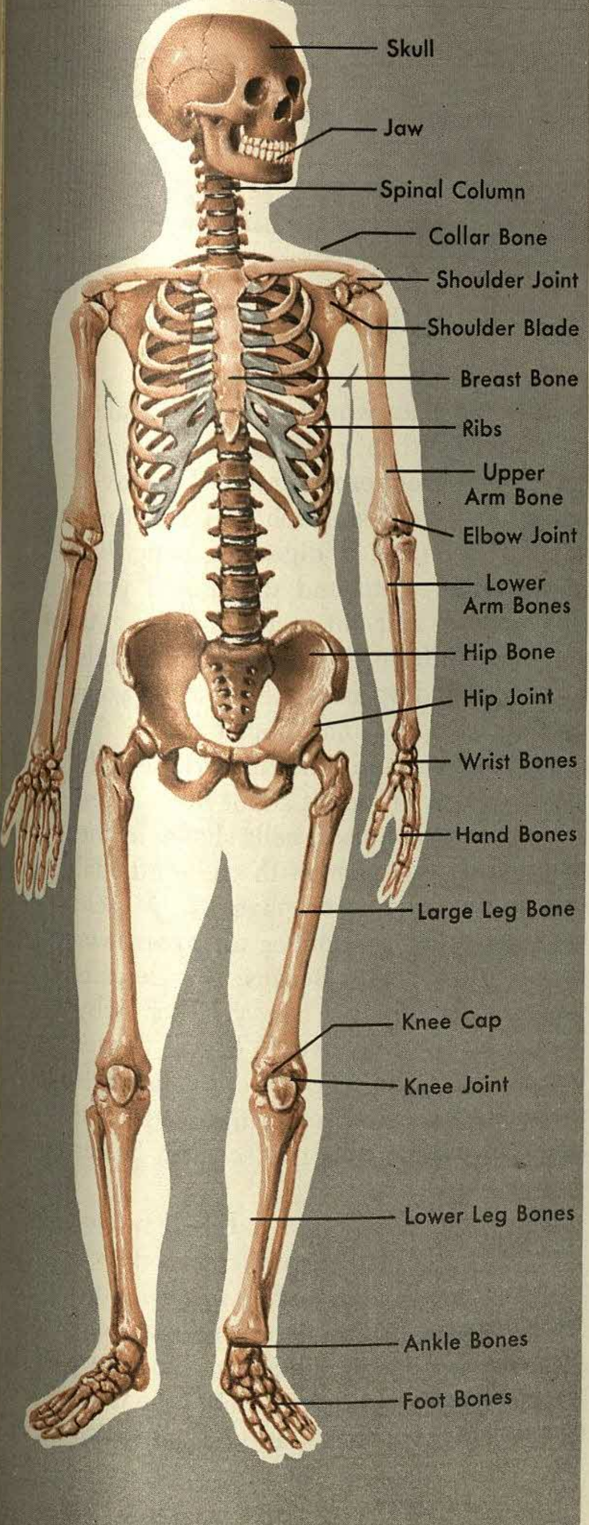
The human body can obtain the materials it needs directly from its environment. It can utilize these to get the energy necessary to keep itself going. The body can use the materials for growth and can produce other organisms like itself. It can do all of these things because of the way in which its cells work together. But the cells of the body must do different kinds of things.

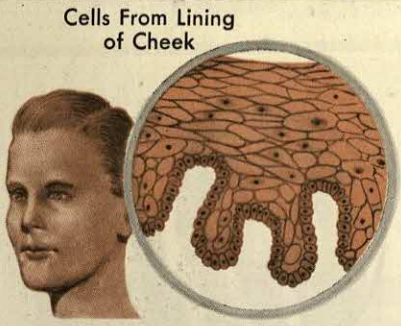
Epithelial Cells

You will recall that the cytoplasm of the amoeba organism is enclosed, or covered, by a cell membrane. The membrane protects the cell by holding the protoplasm together and by allowing some things, but not others, to diffuse through it.

Many parts of the human organism are also covered, and special kinds of cells do the job. A group of cells that does one special kind of job in a many-celled organism such as a body is called a ***tissue.*** The cells which serve as a protective covering in the body make up a tissue called ***epithelium*** (ep-ih-THEE-lih-um). There are different kinds of ***epithelial*** tissues.

On page 402, it was suggested that you gently scrape the inside of your cheek with the edge of a toothpick. Then you were told to spread some of the scrapings onto a microscope slide and stain them with iodine. If you examined this material with a microscope, you saw cells like those shown on page 457. These cells



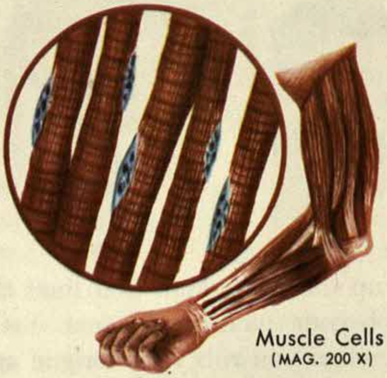


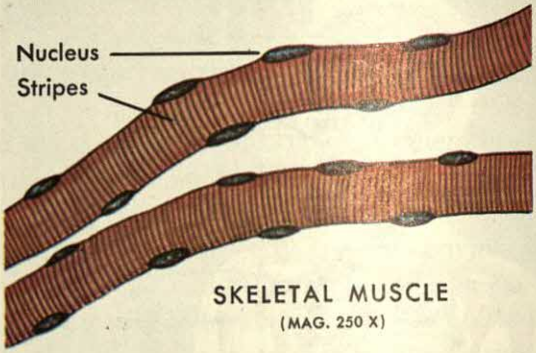
make up the epithelium that lines the inside of your mouth. You can feel this tissue when you rub your tongue against your cheek lining.

Your skin is also covered with a type of epithelial tissue. The skin epithelium is thicker than the cheek epithelium. Dandruff and skin peelings caused by sunburn are also made up of skin epithelium.

You can easily get epithelial cells from your hand for examination under a microscope. Wash and dry your hands. Now carefully scrape the palm of one hand with the edge of a dull knife. Mix some of the scrapings into a drop of water and place on a microscope slide. Stain with a little iodine solution and examine under the microscope.

Wherever there are exposed surfaces in the body, epithelium covers them. The lungs are lined with epithelium, as are the esophagus, stomach, intestines, and blood vessels. The epithelium that lines the interior surfaces of the stomach and intestines not only protects them, but gives off digestive juices as well. The epithelium in the small intestine also permits food and water to diffuse through it. Where else in the body does the epithelium allow materials to diffuse through it?


Muscle Cells
(MAG. 200 X)



SKELETAL MUSCLE
(MAG. 250 X)

The wear on epithelial cells is greater than it is on any other cells of the body. They are constantly being worn away at the surface and replaced by other cells beneath them. If this is happening all the time, why doesn't man eventually run out of epithelial cells?

Muscle Cells

As you may recall, movement is characteristic of living things. If you have ever examined an amoeba under the microscope, you have seen it move. One part of the cell flows in the direction of its movement as another part contracts. It is probable that the protoplasm of all cells can contract to some extent in this way. However, the protoplasm of one kind of cell is especially good at contracting. These are the cells that make up the muscles of our body. By contracting, muscles can move the entire body, as well as many different parts of the body.

Think of all the things that are moving in your body even while you are sitting still. Your heart is pumping away about seventy times a minute. As blood is pumped into your arteries, they expand and contract. You can feel or, possibly, see the movement of an artery in your wrist at the place where your doctor takes your pulse. When you swallow, a wave moves down your esophagus. Other waves move along your stomach and intestines as your last meal is digested. Your diaphragm moves up and down and your ribs move in and out as you breathe. As you look up from this page, your eyelids may close and open as the lenses in your eyes focus upon some object across the room. All these and other important body movements are brought about by muscles.

Compare the muscle cells shown in the diagram on this page with the epithelial cells in the diagram on page 457. Muscle cells generally are longer and narrower than epithelial cells. Because muscle cells contract lengthwise, can you see why long, narrow cells would make better muscle cells? The shape of epithelial cells makes them better covering cells. The shape of muscle cells makes them better contracting cells.

The muscles that move the bones of the body are called ***skeletal*** muscles. Bones are moved only when muscles contract. It is the contraction of several skeletal muscles that enables you to move your forearm up and down. Feel the muscles in your own arm. Can you tell which

INTESTINAL MUSCLE CELLS
(MAG. 250 X)

HEART MUSCLE CELLS
(MAG. 500 X)

muscles are contracting as you move your forearm up and down?

There are two other kinds of muscles in the body. One kind moves the internal organs of the body, such as the stomach and intestines. The other kind is found only in the walls of the heart.

There are two important differences between skeletal muscles and the other kinds of muscles. First, skeletal muscles respond more quickly than the others. Second, you can control your skeletal muscles, but not the others. That is, you can generally move your arm, leg, or head whenever you want to. But you cannot move the muscles of your intestines and your heart because you have no control over them. For these reasons, skeletal muscles are sometimes called ***voluntary*** muscles; the others, ***involuntary*** muscles.

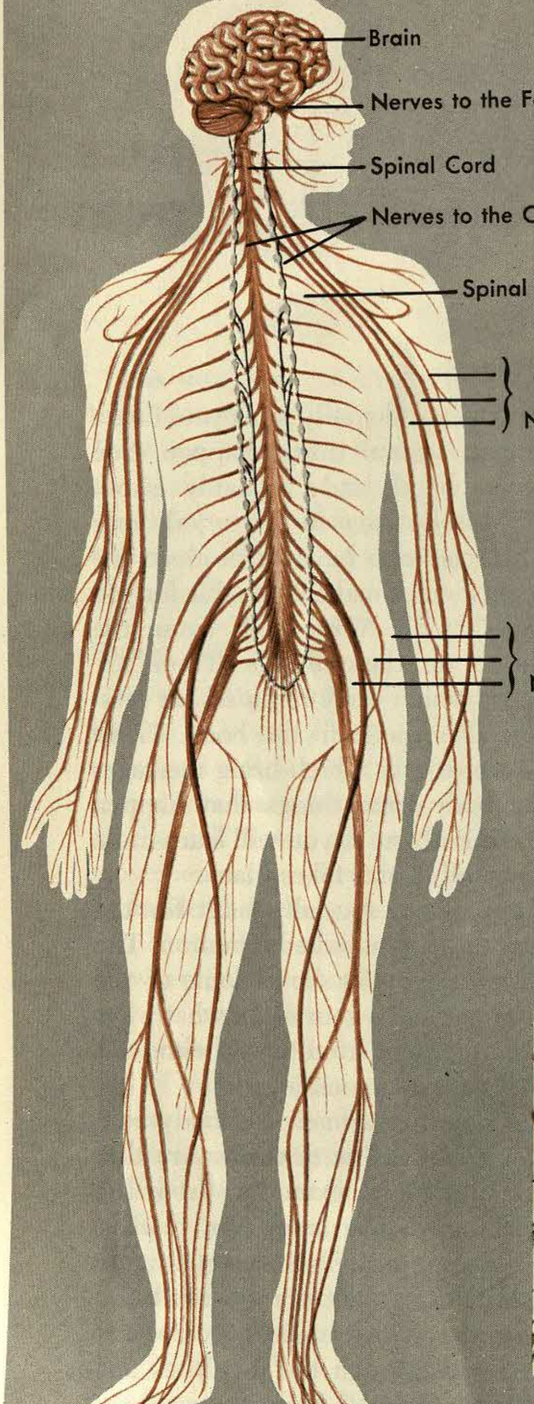
Muscle cells perform a number of important functions in the body. They make it possible for your body to move around. They help digest your food, get air to your blood, and circulate the blood to cells throughout the body. But muscles cannot do all of these things by themselves. There are other cells in the body that cause muscles to contract in the proper places and at the proper times.

Nerve Cells

When you accidentally prick your finger with a pin, several things happen. You jerk your hand and probably shout "ouch!" Muscles have to act to jerk your hand. Muscles also have to produce the movements which make it possible for you to shout "ouch!" ***Nerve*** cells cause the muscles to do these things. There are nerve cells which carry ***impulses,*** or messages, to all muscles in the body. There are also nerve cells which bring messages into the body from things that happen outside. In Problem 2, you will learn more about how all of this takes place.

A nerve cell is specially built for the job it has to do. It is called a ***neuron.*** The diagram on page 460 shows some of the important parts of a neuron. In what ways is its form different from that of either an epithelial cell, or a muscle cell?

The neuron has a main cell body containing a nucleus. The ***dendrites*** are thin fibers of protoplasm extending from the main cell body. The ***axon*** is a thicker, longer fiber of protoplasm extending in the opposite direction from the dendrites. Messages, or nerve impulses, come into the cell body through the dendrites and go out from the cell body through the



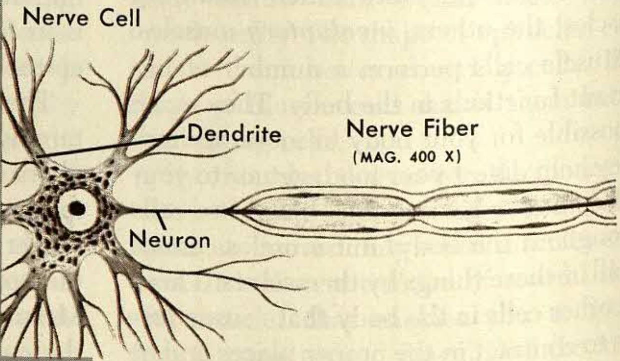
axon. Some axons are as long as three or four feet. They have to be that long to reach all parts of your body. A nerve is made up of a bundle of fibers from a number of different neurons.

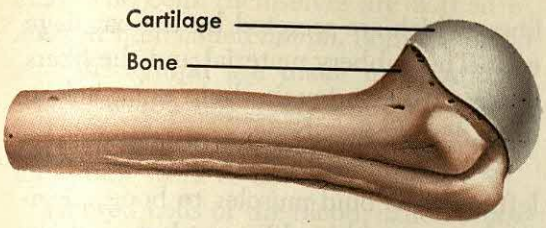
By now, you should have seen that the form of a cell in your body is related to the kind of work it has to do. This is an important idea in biology. It is stated in this way: *"The structure of a cell is related to its function."* Can you tell why the neuron is considered one of the best examples of this biological idea? See how the idea applies to other body cells.

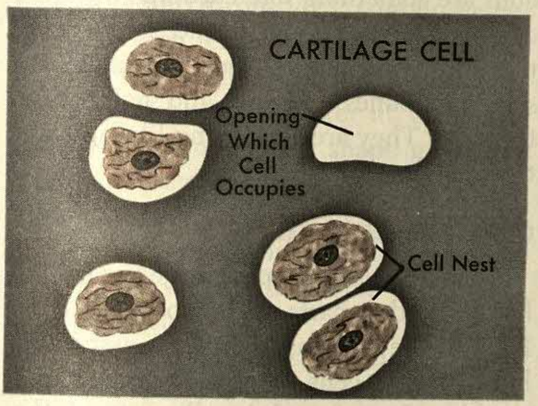
Bone Cells

In a many-celled organism such as your body, there has to be a tissue that supports other tissues. There also has to be a tissue that holds other tissues together in their proper places. This tissue is called the ***connective tissue.***

As you know, your body is supported by the bony framework which is called the skeleton. The skeleton not only sup-







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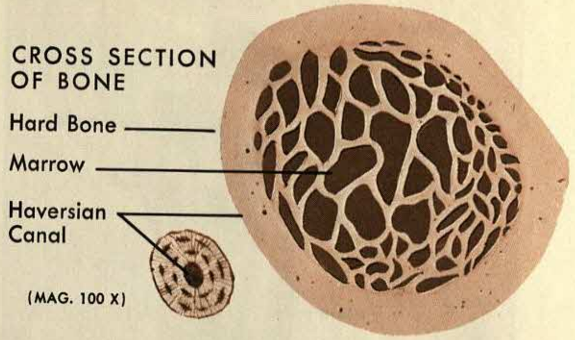


Cartilage cells at left go to make up the cartilage which cushions the ends of bones as shown at top.

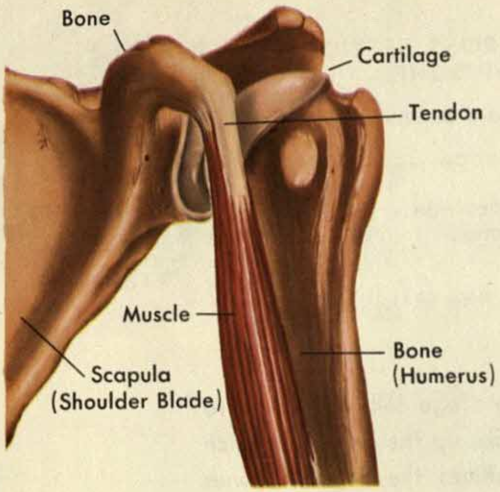
ports the body, but it makes it possible for you to move about. Certain parts of the skeleton also protect important organs. What organs are protected by the ribs and by the skull?

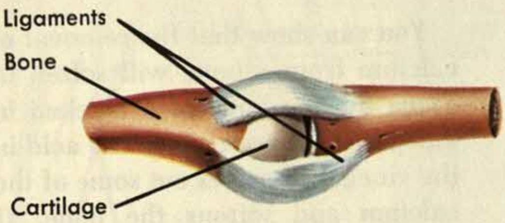
Bones are composed of ***bone*** cells and materials which bone cells have made. The diagram at the top of this page shows you a cross section of a bone such as the one in your arm. Groups of the bone cells are embedded in the hard part of the bone. The cells in each group are arranged in circles around a very small tube called a *canal*, which runs up through the hard bone. Each of the canals contains a blood vessel. Strands of protoplasm extend out from each cell. Surrounding each cell is hard material made up of a compound of phosphorus and calcium, which is secreted by bone cells. This material is what makes the bones hard and strong.

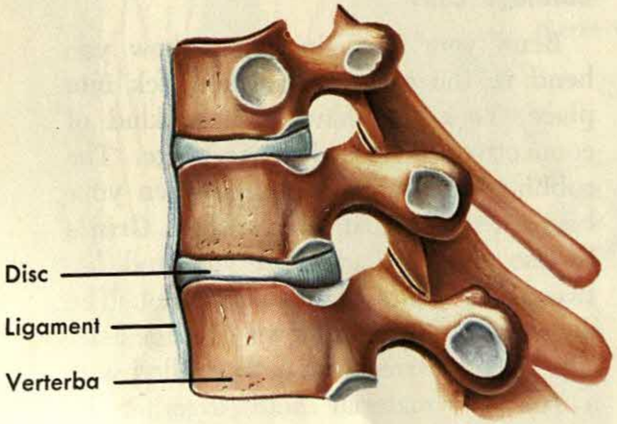
You can show that the removal of calcium from a bone will soften it. Place the leg bone of a chicken in vinegar for a week or so. The acid in the vinegar dissolves out some of the calcium and softens the bone. If you leave the bone in vinegar long enough, it becomes so soft that you can tie it into a knot.

Cartilage Cells

Bend your ear. No matter how you bend it, the ear always goes back into place. Your ears have another kind of connective tissue called ***cartilage.*** The rubbing surfaces of joints between your bones are cushioned with cartilage. ***Gristle*** is also the cartilage that you find between the joints of a chicken leg. The diagram on this page shows cartilage cells. The space between the cells is filled with a rubbery material held together by







fibers which are secreted by the cartilage cells. This rubbery material and the fibers make cartilage tough, but, nonetheless, more flexible than bone.

As you can see in the diagram at the left, ***tendons*** bind muscles to bones. Tendons are something like cartilage, but because all the fibers run in the same direction, they are much stronger. ***Ligaments*** surround bones at joints and hold them together. They are something like an elastic bandage.

Other Connective Tissue

Finally, there is a connective tissue that holds all other parts of the body together. It binds the neurons together in nerves. It holds muscle cells together in bundles of muscles. It is found in all parts of the body. The cells and fibers making up this connective tissue are shown in the diagram on page 463. Remember, the cells in the tissue secrete the fibers.

As you know, most of the meat you eat is actually the muscles of the animal from which it came. The next time you have a roast for dinner, save a piece of the cooked meat. After dinner, separate the piece into the small bundles, or strands, of which it is composed. Each of these is a bundle of muscle fibers. Find the connective tissue that holds the bundles together. What happens to connective tissue when meat is cooked?

Blood Cells

As you will recall, there are two kinds of fluids that circulate through the body. Blood carries food and oxygen to all body cells. The cells themselves are bathed in another fluid called ***lymph.*** Both the blood and the lymph are made up mostly of water, which has many things dissolved in it. Blood also contains cells which have important work to do.

The red cells of the blood, called ***erythrocytes*** (ih-RITH-roh-sytz), contain hemoglobin which carries oxygen from the lungs to body cells. Note that a red blood cell is disc-shaped—thicker at the edges than at the center. This shape gives it a greater surface than if it were the same thickness from edge to edge. With more surface, its hemoglobin can pick up more oxygen. Its shape, therefore, makes it a better oxygen carrier.

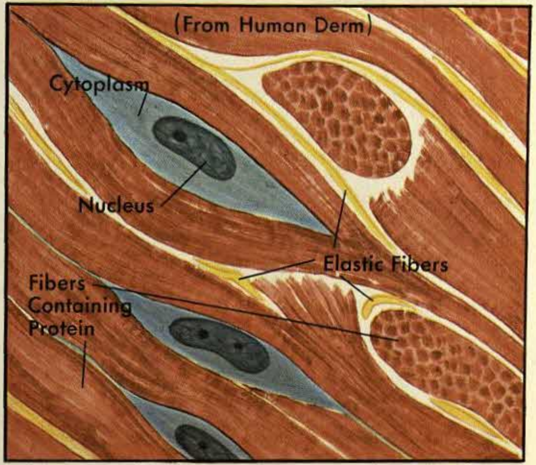
The white blood cells, called ***leucocytes*** (LOO-kuh-sytz), destroy harmful organisms such as bacteria which may get into the body. As you will see on this page, they are shaped something like an amoeba. Because of this, it is possible for them to move about within the fluids of the body and to squeeze through small openings. There are five kinds of white cells, some of which are found in the lymph surrounding all cells of the body.

Platelets (PLAYT-litz) are the third kind of cell found in the blood. When a blood vessel is cut, platelets near the spot break down and release enzymes that start the blood-clotting process.

Cells in Other Living Things

The idea that the structure of cells is related to their functions applies to all living things. Each of the different kinds of cells that make up the human body are also found in many other animals. Which ones would you expect to find in each of

CONNECTIVE TISSUE CELL



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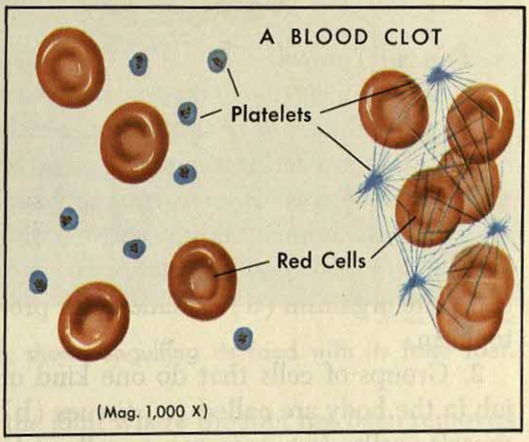
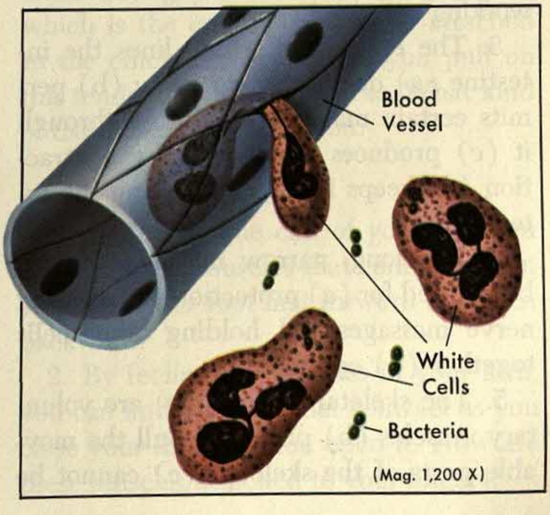




the animal groups listed on pages 394–395?

Take another look at the cells of a green leaf shown on page 400. How is the structure of these cells different? How is their function different? Just as different kinds of animal cells make up different kinds of animal tissues, so different kinds of plant cells make up different kinds of plant tissues. Each kind of plant tissue has certain functions to perform. What are some of the functions that the different kinds of plant cells have to perform?

SUMMARY

The human body is made up of different kinds of cells. Each kind performs a different function. Working together, they keep the body operating as one organism.

Activities

A. *Testing Yourself*

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. An amoeba is different from any single cell in the human body because it (a) is alive (b) uses food for energy (c) is a complete organism (d) is made up of protoplasm.

2. Groups of cells that do one kind of job in the body are called (a) tissues (b) muscle cells (c) messenger cells (d) working cells.

3. The epithelium which lines the intestine (a) does not wear away (b) permits certain materials to diffuse through it (c) produces movements by contraction (d) keeps food from leaving the intestine.

4. The long, narrow muscle cells are best suited for (a) protection (b) sending nerve messages (c) holding other cells together (d) contraction.

5. The skeletal muscles (a) are voluntary muscles (b) push and pull the movable parts of the skeleton (c) cannot be controlled (d) hold the different tissues of the body together.

6. The fibers of protoplasm extending from the main cell body of a nerve cell are called (a) neurons (b) cilia (c) dendrites and axons (d) connective tissue.

7. The structure of a cell is related to its (a) nucleus (b) function (c) position in the body (d) cell membrane.

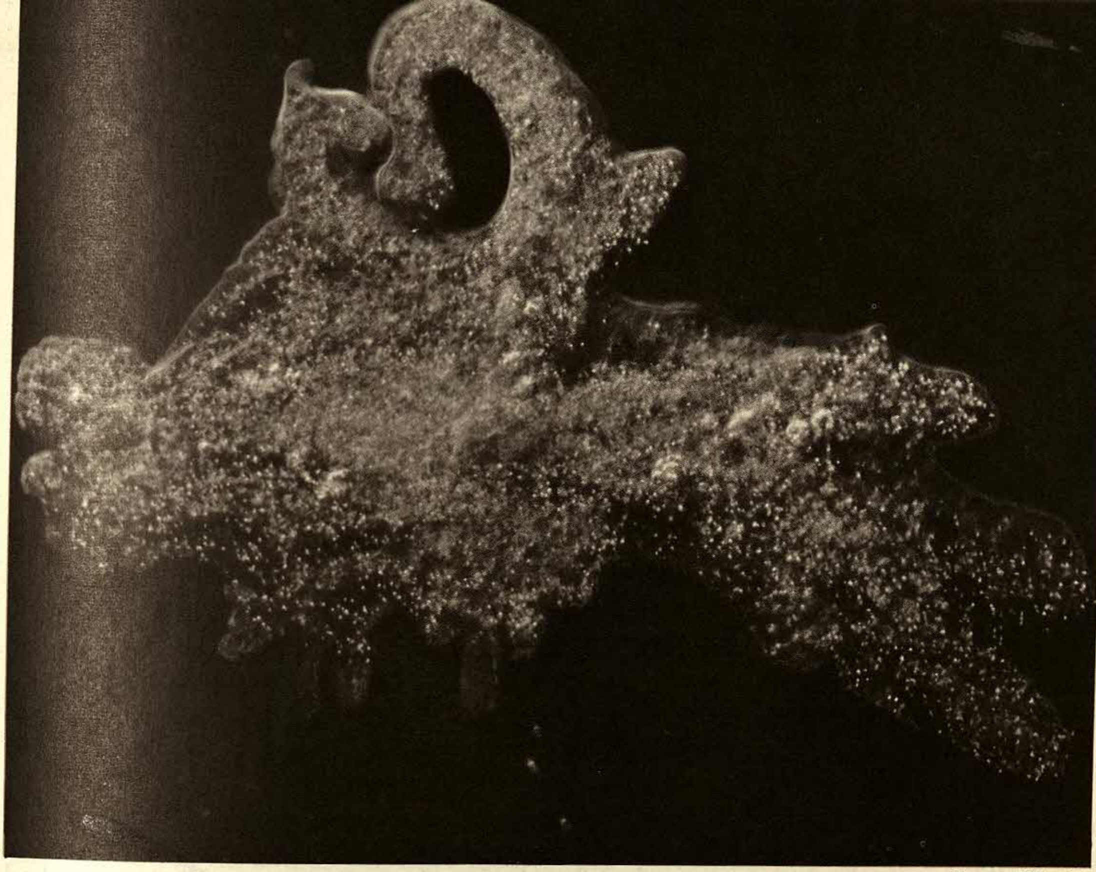
8. The supporting tissue in the outer ear is (a) bone (b) ligament (c) tendon (d) cartilage.

9. Muscles are attached to bones by (a) cartilage (b) ligaments (c) tendons (d) epithelial tissue.

10. The cells of the body which are most like an amoeba are the (a) white blood cells (b) red blood cells (c) bone cells (d) muscle cells.

B. *Examining Amoebas*

Amoebas can be found on the surfaces of leaves which have been submerged around the edges, or at the bottoms, of ponds. Collect a number of these leaves and scrape the surfaces of each onto a



Roman Vishniac

Greatly magnified view of a fresh-water amoeba, shown engulfing its food with its false foot.

microscope slide. Examine with a microscope. Once you have found amoebas, observe the way in which they move about in search of food.

C. Locating Cartilage and Tendons

1. The next time you have roast chicken at home, save the carcass. Locate places where there is cartilage. What is the advantage of having cartilage in these places? Locate places where tendons have been attached to the bones. Why is it difficult to get the meat off such bones?

2. If you can get the foot of a chicken before the chicken is cooked, you can demonstrate how the toes are closed. At the joint where the foot has been removed from the leg, you will see a white object, which is the end of the tendon attached to the chicken's toes. When you pull on this tendon, the toes will close. What kind of tissue makes up a tendon?

D. Locating Muscles

1. By feeling the calf of your leg, you can locate the muscles that contract when you bend your foot first forward and then backward.

2. By feeling the muscles in your arm, you can find the ones that contract as you close your fist and then open it. How are these muscles attached to your fingers?

Lanks from Monkmeyer

PROBLEM 2: HOW DO PARTS OF THE HUMAN BODY WORK TOGETHER?

How much do you weigh now? How much did you weigh when you were born? How much taller are you now? As an example, think of someone who now weighs 140 pounds. For easy comparison, say he weighed 7 pounds at birth. Say, also, that he was 21 inches long at birth and is now 63 inches tall. This means that he is now 20 times heavier and 3 times taller than at birth. You explain this by saying that he has grown. But what does that mean? Does it mean that there are 20 times more cells in his body than at birth? Or does it mean that his cells are 3 times bigger and 20 times heavier?

GROWTH OF THE BODY

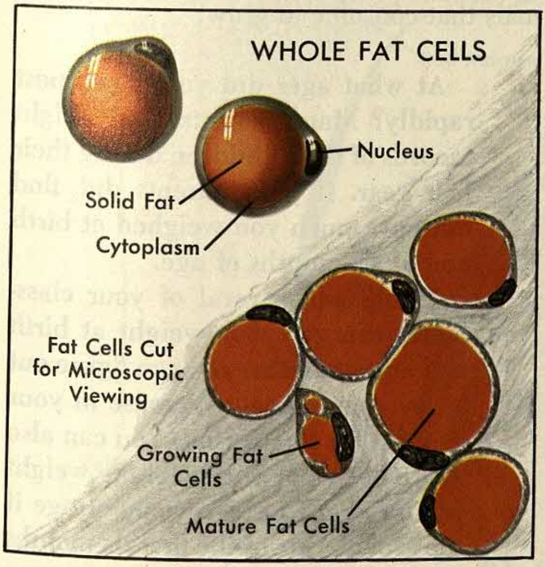
At the time that you were born, your body had billions of cells. All of them developed from a single fertilized egg cell in four important ways. First, there had to be a number of cell divisions in order to produce the billions of cells that make up your body. Second, each of these cells had to grow by building more protoplasm. Third, at different times during these divisions, some cells had to become epithelial cells, some nerve cells, some muscle cells, and so on, to produce the different body tissues. Fourth, the tissues had to become organized into a brain, esophagus, stomach, intestine, heart, blood vessels, and the other organs. And the organs had to be in their proper places within the various systems of the body. All these things had to happen during the nine months before birth when the individual was being formed. Of course, most tissues continue to grow by multiplication of cells. There are many questions about this development that scientists still cannot answer, but they are working on them.

Development of Fatty Tissue

How do you grow from infancy to adulthood? In some tissues, the cells multiply many times. But nerve cells grow in size rather than in number. In some parts of your body, certain cells in your connective tissue store unused food as fat. These, known as ***fat cells,*** are shown in the diagram on this page. Note how large the cell becomes in order to hold the droplet of fat.

Have you ever seen chunks of suet taken from beef? When the cow is alive, a large piece of suet is made up of millions and millions of fat cells. These masses of fat cells make up ***fatty tissues.***

Have you ever noticed how red a newborn baby looks? Generally, the babies that are so red do not, as yet, have much fatty tissue in the skin. The blood vessels showing through the thin skin make it red. As fatty tissue develops, the redness usually disappears. Fatty tissue helps to smooth out the body. It also helps reduce heat loss from the body by serving as a heat insulator.



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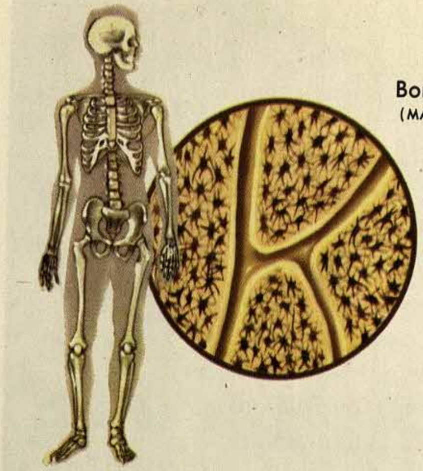
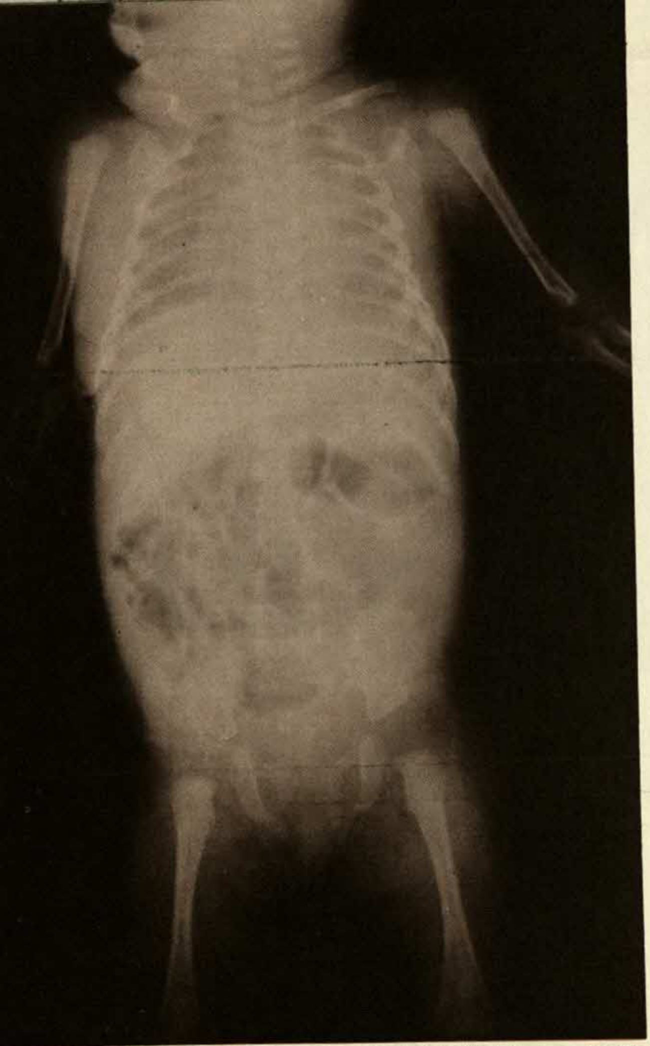


Bacon is meat that is taken from the sides of a pig. If you can examine a slab of bacon which still has the rind on it, you will see several kinds of tissue. The rind is made up of the different tissues that formed the skin of the pig. Most of the bacon is fatty tissue that was formed under the skin. The lean part of the bacon is muscle tissue.

How could you use strips of fatty bacon tissue to demonstrate that fat reduces heat loss?

Development of Bones

When you were born, you had the framework of your present skeleton, but all of your bones had not yet been formed. Much of your skeleton was made up of cartilage. The x-ray picture on page 468



The Children's Hospital Medical Center—Boston

X-ray photograph of child's skeleton shows where cartilage has not yet formed into bone.

shows the places where bone has not yet formed in the skeleton of a baby. All of your bones will not be completely formed until you have finished growing. As bone cells develop in the cartilage and deposit calcium and phosphorus, bones not only get larger, but they get heavier and more rigid, too.

You may wonder if cartilage is strong enough to serve as part of a baby's skeleton. Have you ever tried to cut through, or chew, gristle in meat? As you will recall, gristle is cartilage.

Development of Other Tissues

As the bones grow longer, muscle cells must also grow longer. Nerve cells must get longer along with muscles. The tissues making up blood vessels must also grow, along with bone and skeletal muscles, in order to keep their cells supplied with food and oxygen. The growth of each tissue must keep up with all the others so that the growing body can operate properly.

After a while, you stop growing. Most people complete their growth by the time they are about twenty years old. Something happens to the cells of the body which either halts their growth, or regulates them so that the body gets no taller. But there are some plants and animals that continue to grow as long as they live. Can you name any of the plants and animals that continue to grow?

At what ages did you grow most rapidly? Many parents keep weight records of their children during their first year. If your parents did, find out how much you weighed at birth and at six months of age.

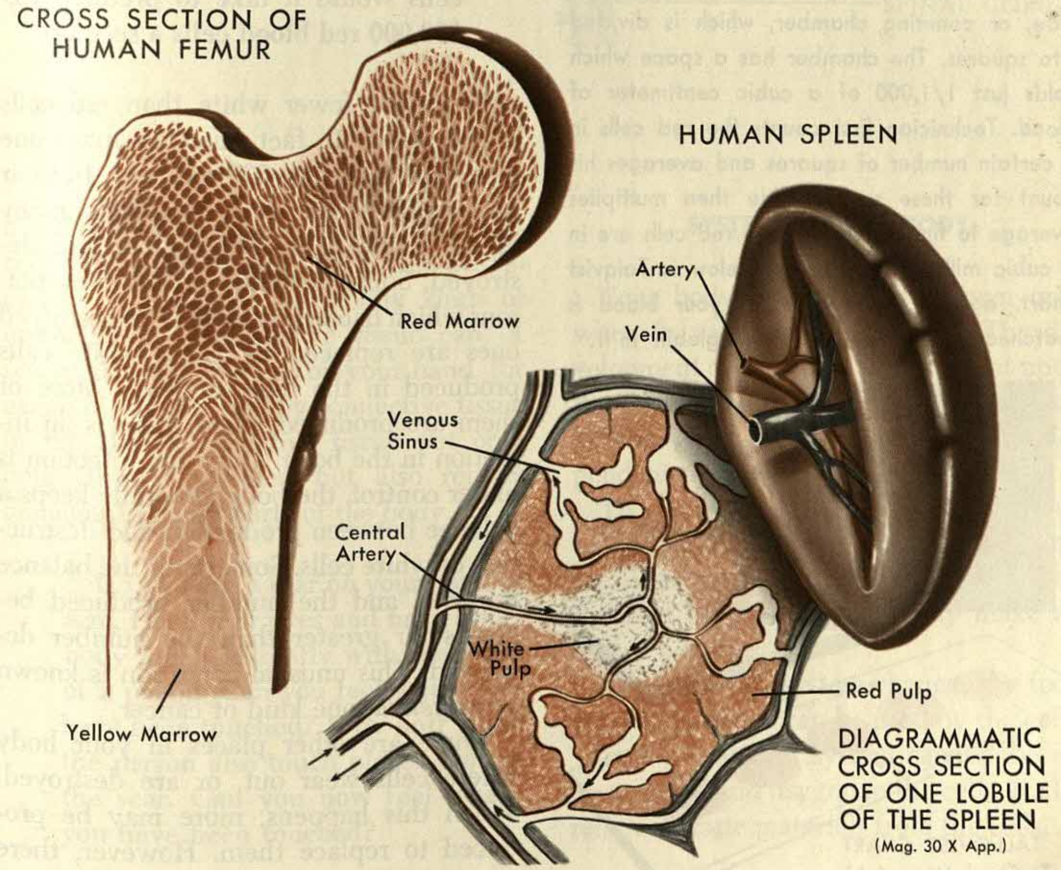
If you and several of your classmates can get your weight at birth and at six months, you can figure out an average percent increase in your weights for this period. You can also figure out what your average weight would be at fourteen years of age if the growth rate of the first six months was maintained.

Replaceable Cells

Some of your cells are destroyed or worn away at an astonishing rate. This started even before you were born, and it will continue as long as you live.

Rub your hands together. When you do this, you rub away hundreds of cells. The outer epithelial cells covering your skin are being worn away whenever any part of your body rubs against something. This is going on all the time. You should not be too concerned about the loss of these cells, because they are actually dead cells. You experience this loss on a grand scale after a bad sunburn. The healing of a blister on your foot is other evidence of the ability of the body to replace dead, worn-out epithelial cells.

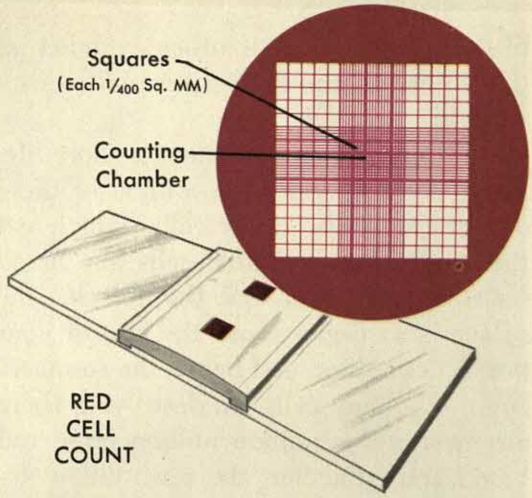
Red blood cells also have a short life. Every second, about ten million of them are destroyed by other cells, which eat them up. These cannibal cells line blood vessels in the liver and the ***spleen.*** The spleen is an organ about the size of your fist. It lies behind and below the stomach. Although many cells are destroyed, there are twenty-five million million or so red blood cells. Further, the ten million destroyed are replaced at the rate of ten million a second by young red cells pro-



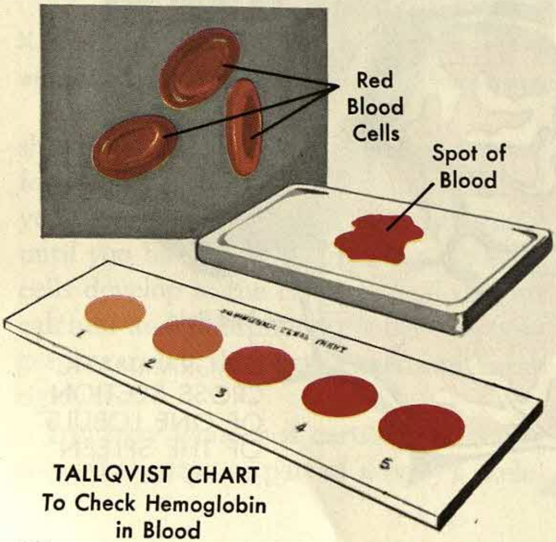
CROSS SECTION OF HUMAN FEMUR

HUMAN SPLEEN

DIAGRAMMATIC CROSS SECTION OF ONE LOBULE OF THE SPLEEN
(Mag. 30 X App.)



Counting chamber, shown above, is used by laboratory workers for blood analysis. A blood sample, diluted with salt water, is placed on slide, or counting chamber, which is divided into squares. The chamber has a space which holds just 1/1,000 of a cubic centimeter of blood. Technician first counts the red cells in a certain number of squares and averages his count for these squares. He then multiplies average to find out how many red cells are in a cubic millimeter of blood. Below is Talqvist chart, against which color of your blood is matched to test amount of hemoglobin in it.



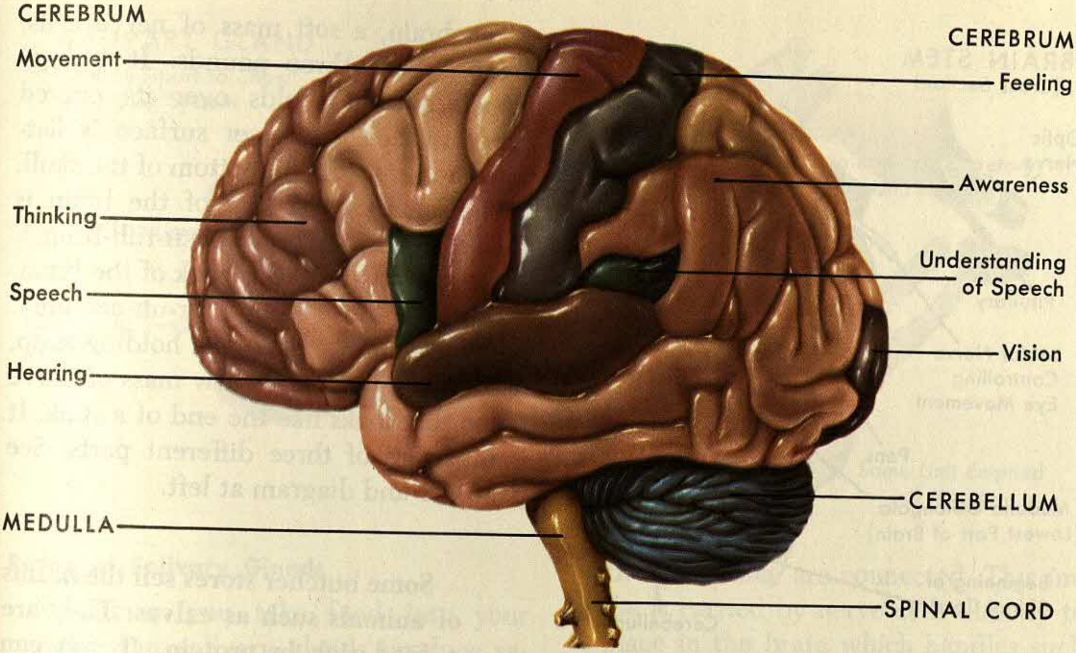
TALLQVIST CHART
To Check Hemoglobin in Blood

duced by cells in the bone marrow. The body generally keeps a balance between the number of red cells produced and the number destroyed. However, when production falls behind destruction, a condition called ***anemia*** results. Another type of anemia is caused by inadequate hemoglobin in red cells.

Red cells are formed by division of certain cells in the bone marrow. These might be called *mother cells.* Each time a mother cell divides, red cells are produced. Suppose that it takes one hour for one of the mother cells to divide. How many mother cells would it take to produce 10,000,000 red blood cells a second?

There are fewer white than red cells in the blood. In fact, there is about one white cell for every 600 red cells. In their battle against invading organisms, many of the white cells of the blood are destroyed. Some of them are killed by poisons which bacteria release. The destroyed ones are replaced by other white cells produced in the bone marrow. More of them are produced when there is an infection in the body. Once the infection is under control, the body generally keeps a balance between production and destruction of white cells. Sometimes the balance is upset, and the number produced becomes far greater than the number destroyed. This unusual condition is known as ***leukemia,*** one kind of cancer.

There are other places in your body where cells wear out, or are destroyed. When this happens, more may be produced to replace them. However, there



are limits to this replacement plan. Neither nerve nor muscle cells can be replaced in this way. But many kinds of epithelial and connective tissue can. A scar that heals on a cut on your hand, for example, was formed by connective tissue in the skin. Connective tissue not only holds things together, but also repairs damages in many parts of the body.

If you have a scar on your hand or arm, close your eyes and have somebody touch it lightly with the point of a pencil. Can you feel where you have been touched? Why not? Have the person also touch places around the scar. Can you now feel where you have been touched?

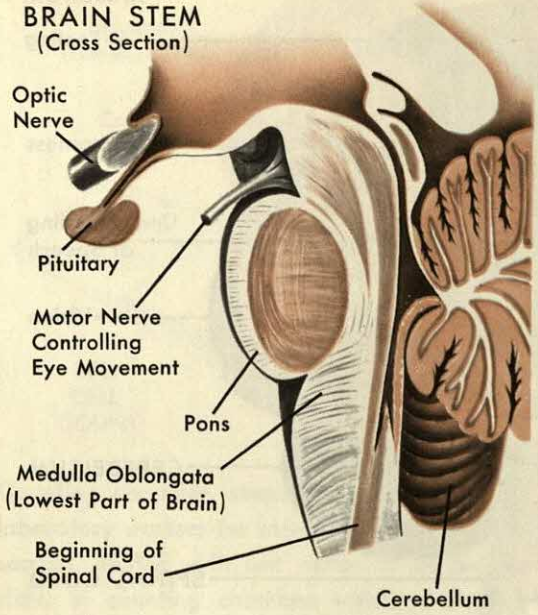
SYSTEMS OF THE BODY

Your body becomes fully grown only when its various parts develop. The development of each part is dependent upon the development of other parts. The way in which each part does its job is also dependent upon the other parts.

To keep your body alive, its cells must be supplied with food and oxygen, and the cells' wastes must be removed. The different systems of your body make all of this possible.

Your digestive system changes the food you eat so that it can be used by the cells.

Your circulatory system carries the digested food and oxygen to the cells. It also removes waste materials from the cells.



BRAIN STEM
(Cross Section)

Optic Nerve
Pituitary
Motor Nerve Controlling Eye Movement
Pons
Medulla Oblongata (Lowest Part of Brain)
Beginning of Spinal Cord
Cerebellum

Your respiratory system keeps the blood supplied with oxygen and removes carbon dioxide and water.

Your excretory system, which includes the kidneys and sweat glands, removes other wastes from your blood.

You can see how important it is that all of these systems work together. If one fails to do its work properly, all others will be affected.

There are two ways in which the activities of each system are controlled. One way is through the nervous system. The other way is through chemicals that are secreted by certain cells in the body.

THE CENTRAL NERVOUS SYSTEM

The brain and the spinal cord are the two main parts of the central nervous system. See diagram on page 460.

The Brain

The brain, a soft mass of nerve cells, weighs about three pounds. It is egg-shaped and has folds over its curved upper surface. Its lower surface is flattened and rests on the bottom of the skull.

The larger, front part of the brain is known as the ***cerebrum*** (SEH-ruh-brum). The smaller part, at the back of the brain, is called the ***cerebellum*** (ser-uh-BEL-um). Beneath the cerebrum, and holding it up, is the ***brain stem***, a narrow mass of nerve tissue that looks like the end of a stalk. It is made up of three different parts. See page 471 and diagram at left.

Some butcher stores sell the brains of animals such as calves. They are a food rich in protein. If you can obtain a calf's brain from a butcher, examine its general shape. Note the wrinkles, or folds, over its surface.

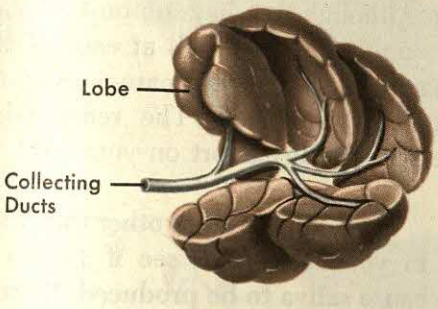
Spinal Cord

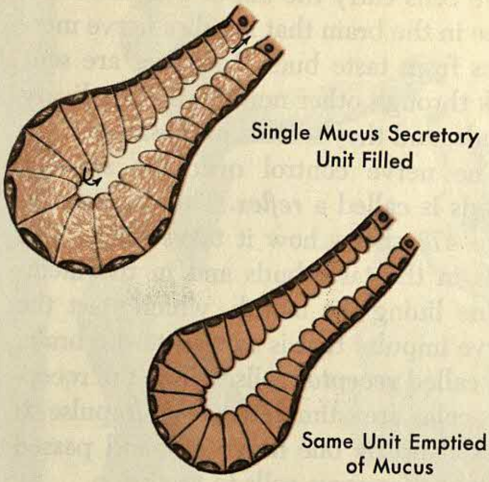
The ***spinal cord***, white and soft, is about a half inch thick. It is made up of nerve tissue, and it lies protected in a bony tunnel formed by the vertebrae of the backbone. Thirty-one pairs of large nerves, called ***nerve trunks***, are attached to the spinal cord. As you can see in the diagram on page 460, the nerve trunks branch into nerves that reach all parts of the body.

The next time you have a chicken dinner at home, ask for the back. You won't get much meat off it, but you can use it for another purpose. Carefully cut, or separate, some of the vertebrae making up the backbone to find the spinal cord inside of it. See if you can find any nerves leading away from the spinal cord.

SALIVARY GLAND

Pulled Apart to Show Duct System




Single Mucus Secretory Unit Filled
Same Unit Emptied of Mucus

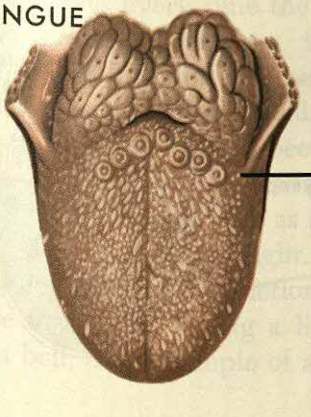
Reflex of Salivary Glands

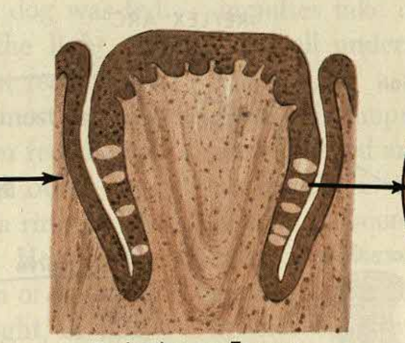
Whenever you take food into your mouth, your salivary glands produce saliva. Why do they do this? One answer is, "because saliva is needed for digestion." But this is not a scientific answer because it doesn't tell why it happens. There is, however, a scientific explanation.

Near the tip and along the sides and back of your tongue are bundles of special cells called ***taste buds.*** The cells in each bud are sensitive to materials taken into the mouth. When these cells are stimulated, they start an impulse in nerve cells with which they are connected. This impulse is carried by nerve cells directly to a place in the brain which handles such messages. From there, an impulse is sent back through other nerve cells to salivary glands, which start secreting saliva.

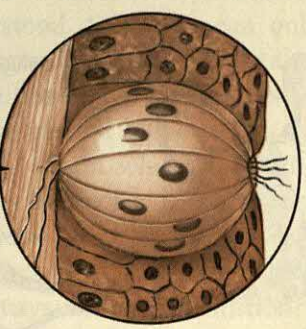
Have you ever noticed how saliva forms in your mouth when the dentist is drilling a tooth? Saliva is also produced when the membrane lining of your mouth is rubbed or injured. When certain cells in the membrane are stimulated by being rubbed, they also start an impulse in nerve cells with which they are connected. The

TONGUE





Projection on Tongue, Surrounding Taste Buds
(Mag. 35 X)



Taste Bud
(Mag. 70 X)

nerve cells carry the impulse to the same place in the brain that handles nerve messages from taste buds. Impulses are sent back through other nerve cells to salivary glands, and they secrete more saliva.

The nerve control over the salivary glands is called a ***reflex.*** The diagram on page 473 shows how it takes place. The cells in the taste buds and in the membrane lining the mouth, which start the nerve impulse that is carried to the brain, are called ***receptor*** cells. When the receptor cells are stimulated, the impulse is picked up by one nerve cell and passed along other nerve cells to the brain.

The branching ends of two nerve cells are not connected directly. As you can see in the diagram, there is a space between them, which is called a ***synapse*** (sih-NAPS). Impulses from one nerve cell to another must pass over a synapse.

Nerve cells in the brain are also connected through other synapses with nerve cells running to the salivary glands. When the impulse is received by nerve cells in the brain, they send out impulses through other nerve cells to the salivary glands. It is these impulses from nerve cells in the brain that cause the salivary glands to produce saliva.

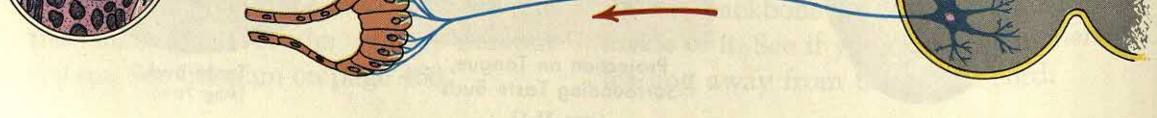
There are several things about the salivary reflex which should be pointed out. There had to be something, such as food or other material, in the mouth to start the reflex. Although the diagram on this page shows only one nerve cell at each of the three stages of the reflex, many nerve cells are actually involved. The reflex takes place without any effort on your part.

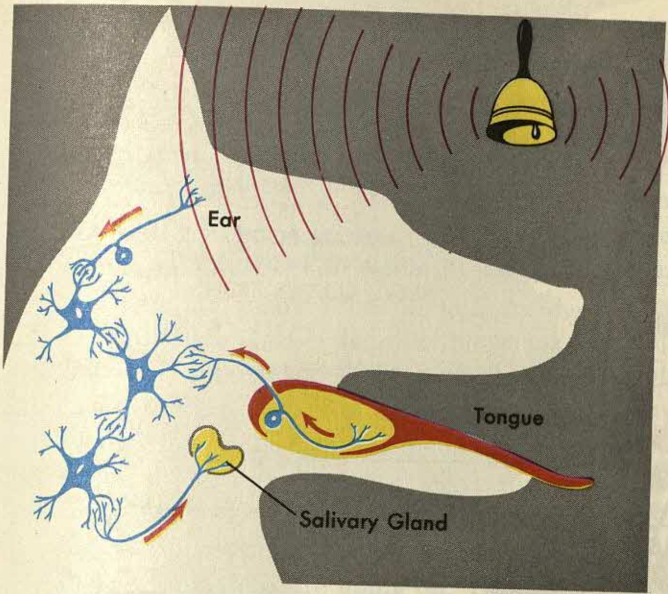
Try holding things other than food in your mouth to see if they will cause saliva to be produced. Be sure that the things which you put into your mouth are clean. Here are some suggestions—buttons, pebbles, and small pieces of wood. On your first try, you might just hold them in your mouth. Next time, you might move them around a bit. How can you tell whether more saliva is produced when one or another object is held in your mouth?

Conditioned Reflex

Why does your mouth water when you see, or hear, about delicious food? A reflex brings this about, but in a more complicated way than the reflex that results from tasting food.

REFLEX ARC





Pavlov's dog learned to salivate at sound of a bell. Other dogs, such as the one at right, learn to sit up and beg for food when they smell it.

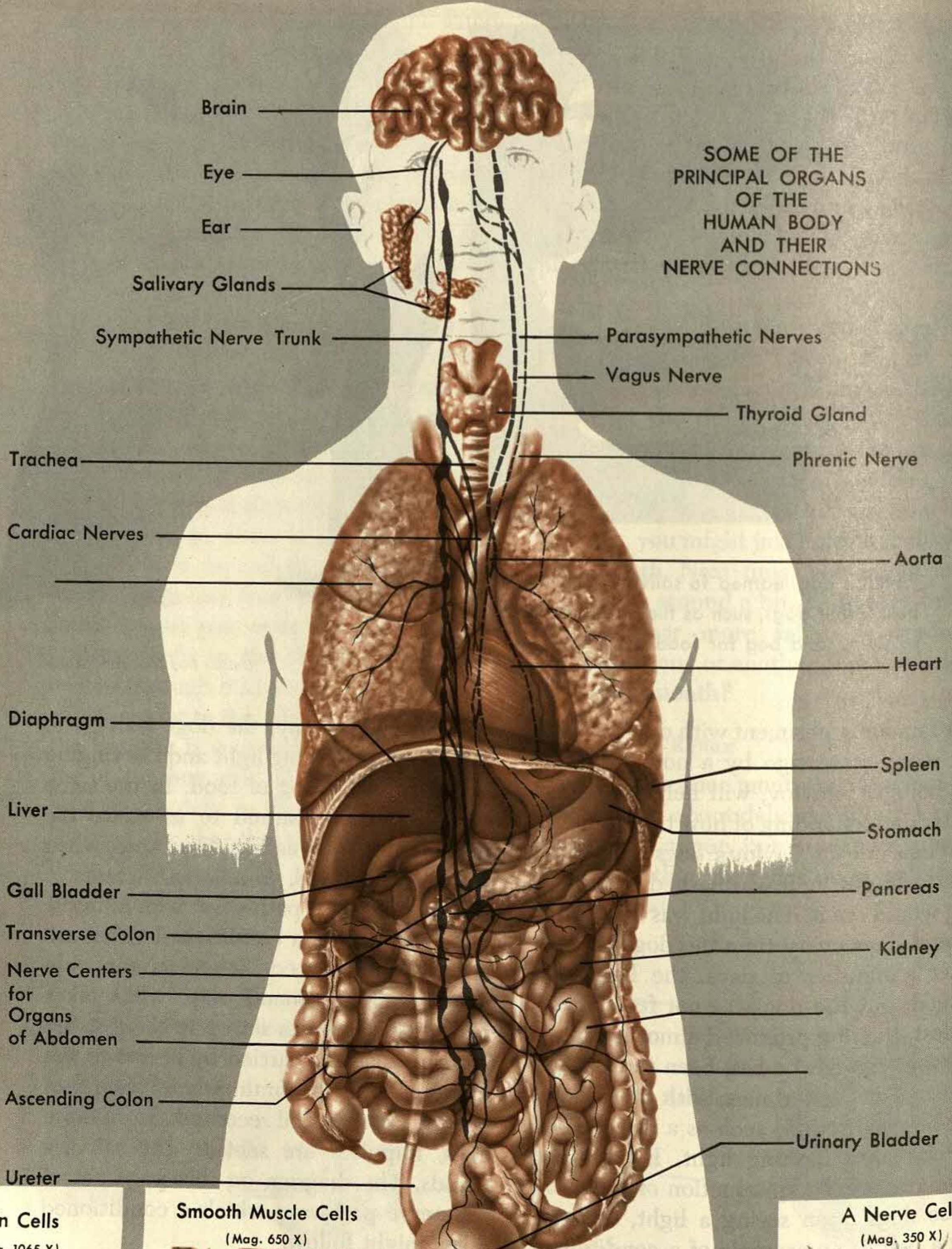
Gaines Dog Research Center

A famous experiment with dogs, carried out many years ago by a noted Russian physiologist, Pavlov, will help you get a better understanding of how this happens.

When one of Pavlov's dogs was given food, a bright light was flashed where the dog would see it. The light was flashed for several days every time the dog was fed. After a number of days, the light was flashed, but the dog was not fed. Nevertheless, the dog produced almost as much saliva as though he had been fed. Pavlov repeated his experiment with other dogs, but he used sounds such as a ringing bell instead of a flashing light. He got the same results. The production of saliva by these dogs upon seeing a light, or hearing a bell, is an example of a ***conditioned reflex.*** In some way, the dogs learned to associate the flashing light and the ringing bell with the eating of food. In the same way, you have learned to associate the sight of food with eating. Therefore, when you see good food, your mouth waters.

The kinds of pathways which nerve impulses take in a conditioned reflex are not well understood. Scientists can only imagine, in a general way, what takes place. The impulses set up in the eyes by viewing food are carried by nerves to the nerve cells in the brain where memories of taste are seen and recorded. From these cells, impulses are sent to the salivary glands. The diagram on this page shows the nerve pathways which a conditioned reflex might follow.

SOME OF THE PRINCIPAL ORGANS OF THE HUMAN BODY AND THEIR NERVE CONNECTIONS

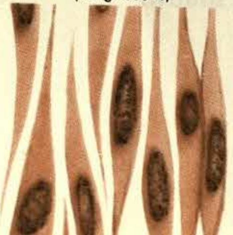


Skin Cells

(Mag. 1065 X)

Smooth Muscle Cells

(Mag. 650 X)

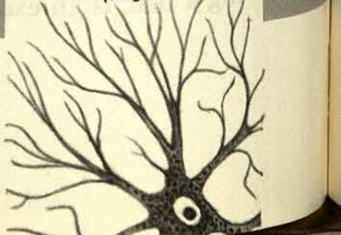


Sympathetics are shown on left side.

Parasympathetics are shown on right side.

A Nerve Cell

(Mag. 350 X)



Involuntary Actions

If you have ever baited a fishhook with an earthworm, you know that the worm begins to squirm as soon as you pick it up. Because the earthworm does not have a brain, it does not feel pain as you do. Its squirming is brought about by reflex action through its simple nervous system.

There are many reflex actions in the body, which take place without your knowing about them. The action of the heart, the production of saliva, the act of swallowing, and the movement in your stomach and intestines are only a few of them. Although they are all controlled by the nervous system, you are not conscious that these actions are going on. They are ***involuntary actions.*** These involuntary actions are carried on through special parts of the nervous system.

Breathing is an involuntary act, but you can consciously control it to a certain extent. You can take a deep breath and hold it for a while. Could a person suffocate by intentionally holding his breath? He might be able to hold it until he became unconscious. As soon as he became unconscious, the reflexes would take over and he would breathe again.

In the diagram on page 476, the paths of nerve connections between some of your organs and the central nervous system are shown. Although all nerve connections are made with the central nervous system, there are other special nerve centers through which nerve impulses that control your body organs must pass.

In the diagram you can see that each organ has two kinds of nerve connections with the central nervous system. One kind is represented by solid lines and the other by dotted. The nerve impulses through each of these connections bring about different actions. For example, the impulses over the nerve connections to the salivary glands, shown by the solid lines, cause them to reduce saliva production. But the impulses carried over the nerve connections shown by dotted lines increase saliva production. Actions of other organs are also controlled by the nervous system.

What starts the impulses that bring about the action in different organs? You have already learned how the action of the salivary glands is started. Here is another example. When food is present in the intestine, certain kinds of impulses are sent to the spinal cord and the brain, which result in greater action in the intestine. When there is little food in the intestine, the impulses that are sent to the spinal cord and brain result in impulses which reduce the action.

Think for a moment of all the things going on in your body which are controlled by your nervous system. In order to bring about these many actions, impulses are racing back and forth through your nervous system at all times—sometimes more of them than at other times—depending upon how active you are. During the day, when you are moving about, studying, thinking, and talking, nerve cells throughout your body are ceaselessly receiving and sending impulses. After a while, they must be given a rest, or they will be damaged. Only sleep makes it possible to rest them. During sleep, fewer nerve cells are active. At that time, the nerve cells involved in seeing, hearing, speaking, and thinking are not so active. Neither are the ones that bring about breathing and heart action. Under these conditions, nerve cells are rested and made ready for the busy time when you are awake and active.

DUCTLESS GLANDS

For some time it was believed that the nervous system alone controlled all bodily activities. One by one certain chemicals were discovered, which regulated a number of things that went on in the body. These chemicals, called ***hormones***, are produced by special groups of cells called glands. In one way, they are like the salivary glands. They take materials from the blood and make special chemicals out of them. But in another way, they are different from the salivary glands.

The salivary glands have tubes through which the saliva they produce passes into the mouth. Hormones are produced in glands that have no tubes or ducts. They are, therefore, called ***ductless*** glands, or ***endocrine*** (EN-duh-kryne) glands. Hormones from endocrine glands diffuse into the blood, which carries them to different parts of the body.

Thyroid Gland

The parts of the body in which the more important endocrine glands are located are shown on page 479. The ***thyroid*** gland produces a hormone ***thyroxin*** (thy-ROKS-sin), which regulates the rate at which the cells of your body use food for energy and growth. When too little thyroxin is produced, persons get fat and tire easily. When too much is produced, they may become thin and nervous.

Place your hand on the front of your neck just below your Adam's apple. Swallow several times. The soft tissue which you feel moving up and down as you swallow is your thyroid gland.

Parathyroids

Embedded in the thyroid are four smaller glands, called the ***parathyroids.*** This word means *near the thyroid.* You could not live without the hormone which they produce. It regulates the amount of calcium and phosphorus in the blood. Calcium, in addition to building strong bones and teeth, is needed to keep nerves and muscles in good shape. When the calcium gets low in the blood, muscles cannot be controlled. Calcium is also needed so that blood clots properly.

Adrenal Glands

One adrenal gland is perched on top of each kidney. They produce several different hormones. One of them, ***adrenalin*** (ad-REN-uh-lin), appears to regulate bodily activities which help you meet emergencies where quick action and strength are required. When a person becomes angry or frightened, adrenalin is produced. As it is carried in the blood throughout the body, it causes the heart to beat faster and harder. It also raises the blood pressure, makes you breathe more deeply, and causes the liver to release extra sugar into the blood. It also slows down movements in the stomach and intestines. Can you explain how these things prepare your body for emergency action? Can you explain why the coach of a football team sometimes tries to get his players angry?

Cortisone (KOR-tuh-sohn) is another hormone produced by the adrenal glands. It has been used to treat certain diseases such as arthritis, a painful inflammation of the joints. In many patients, the pain is relieved so long as cortisone is used.

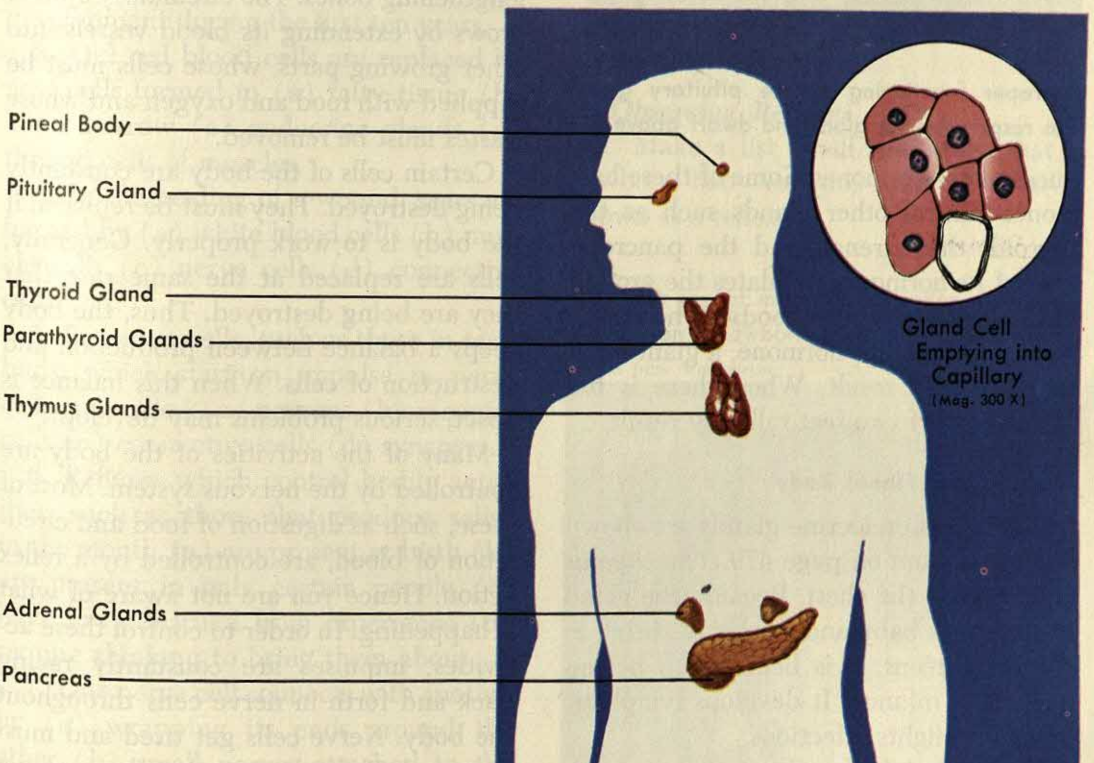
Pancreas

The pancreas is really two glands in one. The larger part of the pancreas produces a digestive juice that is carried through ducts to the small intestine. It also has other gland tissue scattered throughout it, called the ***islands of Langerhans.*** They make up the endocrine gland that produces the hormone ***insulin.*** Insulin is needed to help the body use sugar properly. A lack of the proper amount of insulin results in the disease ***diabetes.***

Pituitary Gland

The ***pituitary*** gland is sometimes called the master gland of the body. It is a small gland at the base of the brain and it pro-

ENDOCRINE GLANDS



Ewing Galloway

Improper functioning of the pituitary gland was responsible for giant and dwarf above.

duces many hormones. Some of these hormones control other glands such as the thyroid, the adrenal, and the pancreas. One of its hormones regulates the growth of the long bones of the body. When there is too much of this hormone, a giant eight feet tall may result. When there is too little, a dwarf two feet tall may result.

Thymus and Pineal Body

Two other endocrine glands are shown in the diagram on page 479. The ***thymus*** is located in the chest. Because the gland is large in a baby and begins to shrink in the early teens, it is believed to be important in infancy. It develops lymphatic tissue and fights infections.

The ***pineal body,*** about the size of a pea, is located on a stalk in the brain near the pituitary.

In most cases, where the endocrine glands do not produce sufficient hormones, doctors can supply them. This is true in the case of the thyroid, parathyroid, the islands of Langerhans, and some of the pituitary hormones. The hormones can be taken from other animals. Some of them can also be made by chemists.

SUMMARY

As your body grows and develops, its different parts must change in order to keep it working properly. Your bones become harder as they grow longer. Muscles and nerves grow longer in step with lengthening bones. The circulatory system grows by extending its blood vessels into other growing parts, whose cells must be supplied with food and oxygen and whose wastes must be removed.

Certain cells of the body are constantly being destroyed. They must be replaced if the body is to work properly. Generally, cells are replaced at the same rate that they are being destroyed. Thus, the body keeps a balance between production and destruction of cells. When this balance is upset, serious problems may develop.

Many of the activities of the body are controlled by the nervous system. Most of these, such as digestion of food and circulation of blood, are controlled by a reflex action. Hence you are not aware of what is happening. In order to control these activities, impulses are constantly racing back and forth in nerve cells throughout the body. Nerve cells get tired and must be rested. The only time that they can get proper rest is when you sleep. Hormones also regulate bodily activities.

Activities

A. *Testing Yourself*

In the proper place on your answer sheet, write the letter of the ending that best completes each statement.

1. At birth, the skeleton (a) is made up entirely of bone tissue (b) is mostly fatty tissue (c) is made up largely of cartilage (d) has not yet begun to form.

2. During growth (a) each of the essential kinds of tissues grows in step with the others (b) bones develop first, then muscles, and, finally, nerves (c) the tissues making up the circulatory system are the last to develop (d) bones complete their development during the first ten years.

3. Old red blood cells are replaced by new cells formed in (a) fatty tissue (b) bone marrow (c) endocrine glands (d) the red cells of muscles.

4. In the healing of a wound, scars are formed by (a) white blood cells (b) muscle cells (c) nerve cells (d) connective cells.

5. Sensitive cells, such as those in taste buds, which start an impulse in nerve cells, are called (a) neurons (b) receptor cells (c) connective cells (d) synapses.

6. Reflexes which control bodily activities, such as those that produce saliva in the mouth (a) are present at birth (b) are present in only certain people (c) have to be learned from experience (d) require thinking to bring them about.

7. One nerve cell connects with another by (a) wrapping its ends around the other (b) small nerves attached to the ends (c) a space called a synapse (d) connective tissue.

8. Because nerve cells use energy in receiving and sending impulses they (a) are soon destroyed (b) soon wear out and must be replaced by new ones (c) are not dependent upon other cells (d) must have rest from time to time.

9. Hormones are carried to different parts of the body by the (a) nervous system (b) circulatory system (c) digestive system (d) excretory system.

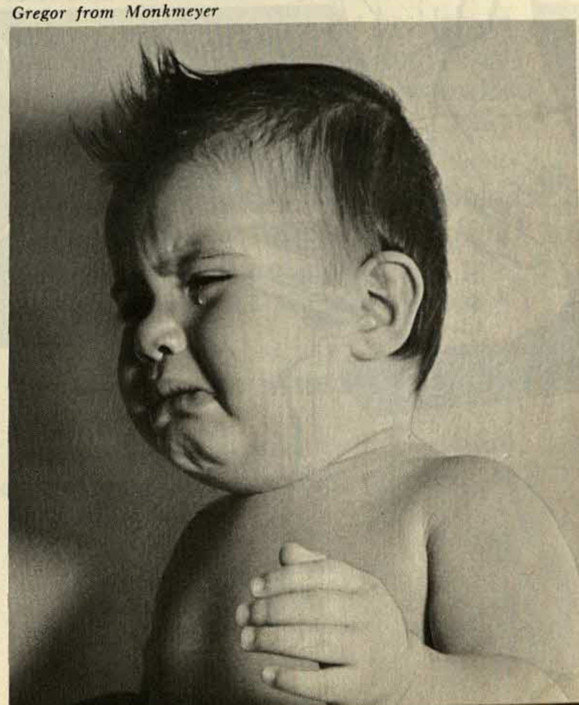
10. The pituitary gland is called the master gland of the body because (a) it is located near the brain (b) it is the largest of all the endocrine glands (c) its hormones control other glands (d) it is found only in large men.

B. *Observing Reflexes*

1. Make a list of all the things that a newborn baby can do. Each of them is known as a reflex.

Crying is one of many simple reflex actions of which even a newborn baby is fully capable.

Gregor from Monkmeyer



2. During a physical examination, have you ever had your doctor tap your knee when your legs were crossed? He did this to see if the nerves in your leg and spinal cord were performing properly. If your leg jerked upward when he tapped your knee, he knew that the nerves were all right. This action is called the ***knee-jerk reflex.*** You can demonstrate it on yourself, or on other students. Can you control it? After you have tried it out, explain what happened in your nervous system.

3. Have another person close his eyes and face the window. After thirty seconds, have him open his eyes. Observe how the pupils in his eyes become smaller. Opening and closing of the pupils, in response to changes in brightness of light, is a reflex. Can you control this reflex?

4. Show that passing your hand in front of the eyes of another person will cause him to blink. This blinking is also a reflex. Can it be controlled?

C. Checking for Skin Receptors

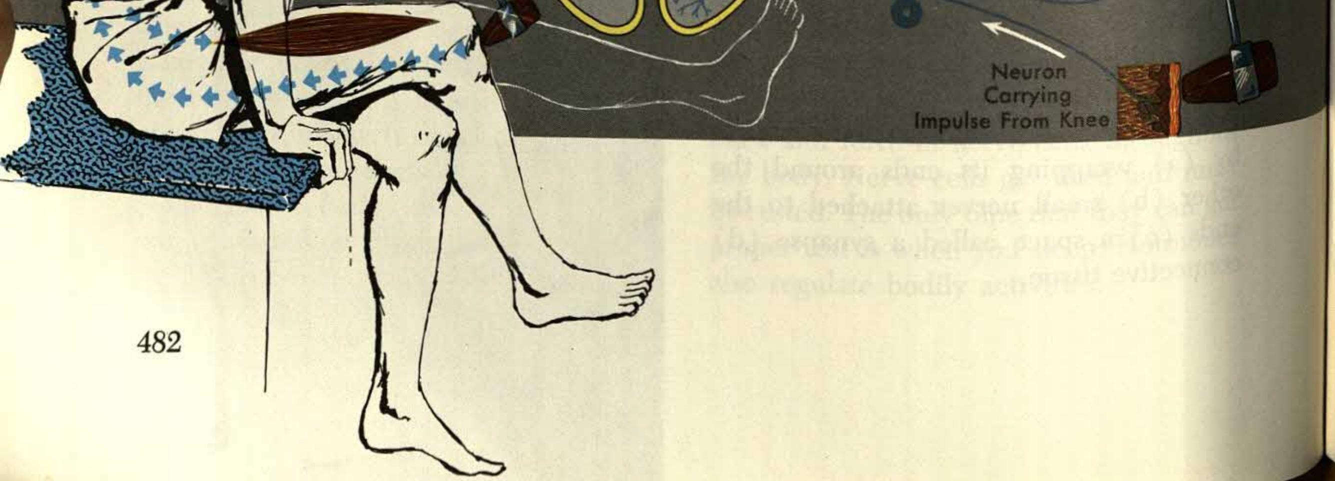
Within the skin are groups of cells called *receptors,* which are especially sensitive to touch, heat, cold, and pressure. Another group is sensitive to pain.

Draw a pencil lightly over the skin on the back of your hand. You feel the pencil because the touch receptors are stimulated. Now press the pencil more firmly against the skin. You feel weight, or pressure, because the pressure receptors pick up pressure of the pencil. If you press harder, you'll stimulate pain receptors.

You can also demonstrate the action of heat and cold receptors by carefully touching the skin in different places. In some places, you'll get the sensation of cold; in others, the sensation of heat.

D. Performing a Breathing Experiment

The rate at which a person breathes is affected by the amount of carbon dioxide in the air he breathes. Count the number of times per minute one of your classmates breathes. Now have him breathe into a paper bag for several minutes. How does his rate of breathing change? If the center which controls the rate of breathing is in the brain, how is it possible for air to affect it?


KNEE-JERK REFLEX
Muscle Cell
Neuron Carrying Impulse to Muscle
Neuron Carrying Impulse From Knee

Julius Fanta from Shostal

When well-balanced meal is eaten in pleasant surroundings, the body benefits most from food.

PROBLEM 3: WHAT KIND OF CARE DOES YOUR BODY REQUIRE?

There are a number of reasons why young people today can look forward to enjoying a longer and healthier life than could young people a hundred years ago. A great deal more is known today about foods and the essential things which they contain. It is also known what happens to the body if it cannot get them. But this knowledge alone will not insure good health to you. This knowledge must be used in selecting the foods which you eat.

More is known about the causes of diseases. A great deal has been learned about the ways in which the body protects itself against them and how you can help the body in its fight. Although it has become possible through man's knowledge of some diseases practically to eliminate them, there are others, such as cancer, which even today are not completely understood.

The effects of drinking and smoking upon the body have not been studied by scientists as intensively as they have studied diseases. Nor has the problem of narcotic drug addiction been considered as seriously as have some other health problems. It is believed by some, however, that these are important problems for many young people. For that reason, some of the evidence obtained from work by authorities on these problems is presented in Problem 3.

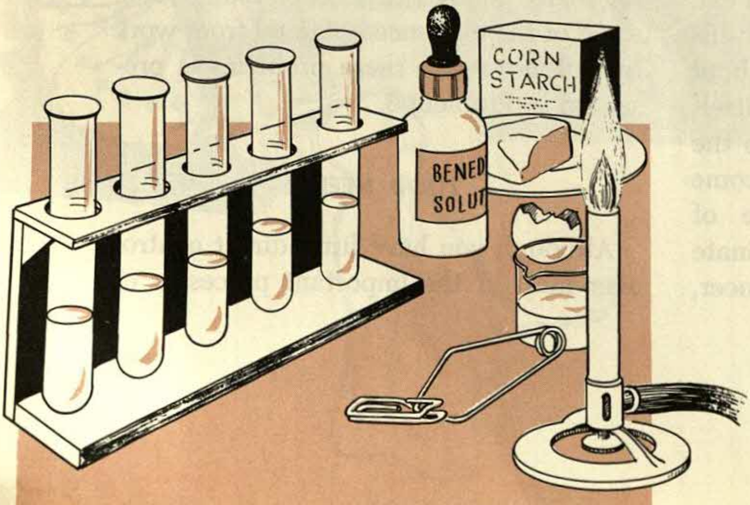
FOOD NEEDS

Although you have little direct control over most of the important processes of your body, many of your daily activities have an indirect effect upon them. Bodily processes, discussed in earlier problems in this unit, are affected by the types of food you eat; how much you eat; your work and your play activities; and the amount of rest you get. In this problem, you will see how bodily processes are affected by your daily activities and you will also learn what you might do to help your body operate more efficiently.

ESSENTIAL NUTRIENTS

Substances in food that supply the body with energy and materials for growth and repair are called ***nutrients.***

You have already learned about three types of nutrients. The starch and sugar in food are grouped together into one type called carbohydrate. Protein is a second type of nutrient, and fat is a third. As you will recall, food made up of carbohydrates, fats, and proteins can be used in the body to supply energy. Proteins are also the nutrients used by protoplasm to build and repair tissues. If the carbohydrates and fats taken into the body are not used immediately to supply energy, they can be stored in the body as animal starch, or as fat.



In your earlier work in science, you probably were shown how to test foods for the presence of sugar, starch, protein, and fat. Here is an experiment you can do to check how well some common tests identify each of these nutrients.

1. Place a small amount of corn syrup (glucose sugar) in one test tube, cornstarch in a second, egg white (protein) in a third, and butter (fat) in a fourth. Add the same amount of water to each of these four test tubes. Add the same amount of water to a fifth test tube and use this as your control. Add a few drops of Benedict's solution to each test tube and boil the contents of each. Watch for color changes.

2. Clean the test tubes and again place a small amount of each food in them as you did above. Add some water and then boil the contents of each tube. Add a few drops of iodine solution. Watch for color changes.

3. Clean the test tubes and again place a small amount of each of the foods in them as you did before. Add some water to each test tube and a small amount of nitric acid. Boil the contents of each gently. Now add ammonium hydroxide a drop at a time. Watch for color changes.

4. Rub a small amount of each of the foods on a piece of white paper. Observe the effects of the food on the paper.

How is the presence of sugar, starch, protein, and fat shown in these tests?

Nutrient Content and Number of Calories in an Average Portion of Various Foods and Beverages

Food	*Percentage by Weight*			*Average Portion*	*Total Calories*
	Protein	*Carbohydrate*	*Fat*		
Avocados	1.7	3.7	26.4	½ pear	259
Bacon (lean)	12.2	1.4	53.0	4 slices	149
Beans, baked	6.0	17.8	0.4	½ cup	99
Beef, roast	19.2	0.0	22.0	¼ pound	303
Beef steak	18.7	1.4	17.0	¼ pound	263
Bologna	14.8	3.6	15.9	4 slices	93
Bread, white	8.5	52.0	2.0	2 slices	130
Bread, whole wheat	9.5	47.0	3.5	2 slices	129
Butter	0.6	0.4	81.0	2 pats	103
Cake, sponge	7.9	54.2	5.0	1 piece	108
Cheese, American	23.9	1.7	32.3	1 slice	110
Cocoa (milk)	4.9	11.9	5.5	1 cup	211
Eggs	12.8	0.7	11.5	one whole	82
Frankfurters	15.2	3.3	14.1	2 links	227
Ginger Ale	—	9.0	—	1 bottle	61
Halibut	18.6	0.0	5.2	¼ pound	81
Ham (fat)	14.6	0.3	44.0	¼ pound	515
Hominy, white	8.5	78.5	0.8	¼ cup	178
Ice cream (vanilla)	3.9	20.3	13.0	½ cup	214
Margarine	0.6	0.4	81.0	1 tablespoon	103
Milk, whole	3.5	4.9	3.9	1 glass	145
Oatmeal	14.2	67.0	7.4	¼ cup	98
Olives, green	1.5	2.8	13.5	5 small	35
Oranges	0.9	10.6	0.2	½ cup juice	48
Peaches, yellow	0.5	11.4	0.1	1 large	49
Raisins	2.3	69.5	0.5	⅓ cup	131
Rice, white	7.6	79.2	0.3	2 tablespoons	98
Root Beer	—	0.8	—	1 bottle	54
Strawberries	0.8	6.9	0.6	12 berries	36

[1] Adapted from *Nutritional Data,* Mellon Institute of Industrial Research, Pittsburgh 13.

Two other types of nutrients are necessary to keep the body operating properly. Certain chemical elements such as calcium, copper, iodine, iron, and phosphorus are often called ***mineral*** nutrients because most of them are obtained by the body from minerals in food. These minerals originally came from the soil or sea water in which the plants grew. The minerals in food are used in building body tissues and in regulating body processes.

The fifth type of nutrient, ***vitamins,*** is one you have probably heard most about.

Although the body does not obtain energy or building materials from water, none of the nutrients could be used in the body without it. A large part of the body is made up of water, and it is needed to carry on all body processes.

Look at the table on page 485. Add the percentages of each nutrient for any one of the foods. You will find that the total is not 100 percent. What other materials are in these foods? Which one makes up most of the remaining material?

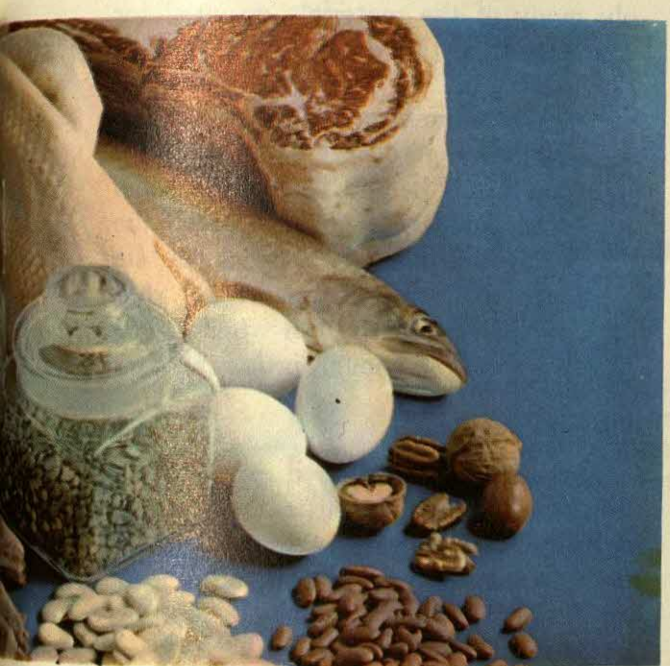
Energy Foods

Foods differ greatly in the amount of energy they can supply. In order to compare the energy value of foods, some measurement of energy is necessary. As you will recall from page 257, the amount of energy that fuels can produce is measured in heat units called calories. The energy value of foods is also expressed in Calories. (This unit is the large Calorie, which is equal to 1,000 small calories.) The number of Calories which a particular food, such as bananas, will supply is determined by using the calorimeter described on page 257.

Meat group, right, which also includes fish, poultry, and dried beans, is principal source of protein for growth.

All photos by National Dairy Council

Carbohydrates in the bread-cereal group, below, will supply energy needs of your body.



From the milk group, below, you get not only proteins, but needed vitamins and minerals.

Vegetable-fruit group, above, will supply you with the vitamins essential for good health.

The table on page 485 shows the number of Calories for average portions of each of the foods. Note which foods have the highest percentage by weight of fats.

Energy Needs of Young People

The amount of energy a person must obtain from his food depends upon his size, age, sex, and on how active he is.

Girls between thirteen and fifteen years of age require 2,600 Calories a day. Boys of the same age need 3,200 Calories. Girls between sixteen and twenty years of age require 2,400 Calories, whereas boys of that age need 3,800 Calories. Boys, therefore, must have more food to supply the additional Calories they need.

If a person does not eat sufficient food of the right kind to supply him with the necessary energy, he will lose weight. The fat stored in his body will be used to supply the needed energy. If he eats more food than is needed to supply energy, the extra food will generally be changed into body fat and cause him to gain weight. It is usually a good idea for boys and girls to have some extra fat in their bodies when they are in this age group.

Proteins for Growth

Boys and girls generally need more proteins than grown men and women. It has been estimated that adult men need about seventy grams of protein a day, whereas boys between the ages of thirteen and fifteen need eighty-five grams. Adult women need about sixty grams of protein a day, but girls between eleven and thirteen years of age need eighty grams. These additional amounts of protein, which are needed by boys and girls, supply their bodies with materials for growth. Protein is the only type of nutrient that will supply many of the materials essential for your growth at this time.

Use figures on this page to find out what percentage more protein you should be getting each day than your parents. If you compared the kinds and amounts of food you ate each day with that eaten by your parents, could you tell whether you were getting enough protein? Why?

Vitamins for Health

The results of controlled experimentation have proved that nutrients other than carbohydrates, fats, proteins, and minerals are essential for good health. Some of these early experiments were as exciting as science fiction.

When you read about the experiments which proved that a lack of certain vitamins resulted in diseases such as beriberi, rickets, and scurvy, you wonder why it took so long for men to find out these things. But once the discovery was made, the search for additional vitamins was carried on most diligently by other scientists. In fact, the discoveries have come so rapidly in the past fifty years that there has been some confusion about naming them. For this reason, you will find that certain vitamins such as B_1 (***thiamin***) have at least two names.

Many different methods have been used by scientists in studies of vitamins. They have fed lopsided, monotonous diets to animals to see what diseases they would develop. They have added other foods to see if they could cure these diseases and analyzed these foods to identify chemicals which might be vitamins. They have

The Heart and the Eye

This insert, consisting of a base drawing and three transparent overlays, shows the course of blood through the four chambers of the heart in a single heart beat. The base drawing of the heart shows a sectioned view of these four chambers. The overlays make it possible to see the changes that take place in size and shape not only of these chambers as blood moves from one to another, but also of the overall size and shape of the heart during the events of the single beat.

On the base drawing, two normal eye diagrams are shown so that both nearsightedness and farsightedness can be explained. Two of the overlays show the causes of these conditions. The third overlay illustrates how the conditions can be corrected by use of lenses.

On the back of this insert are detailed drawings of the eye and of the front and back views of the heart. A study of all the drawings in this insert will give an appreciation and understanding of these two important organs.

Drawings in this insert prepared by ERNEST W. BECK

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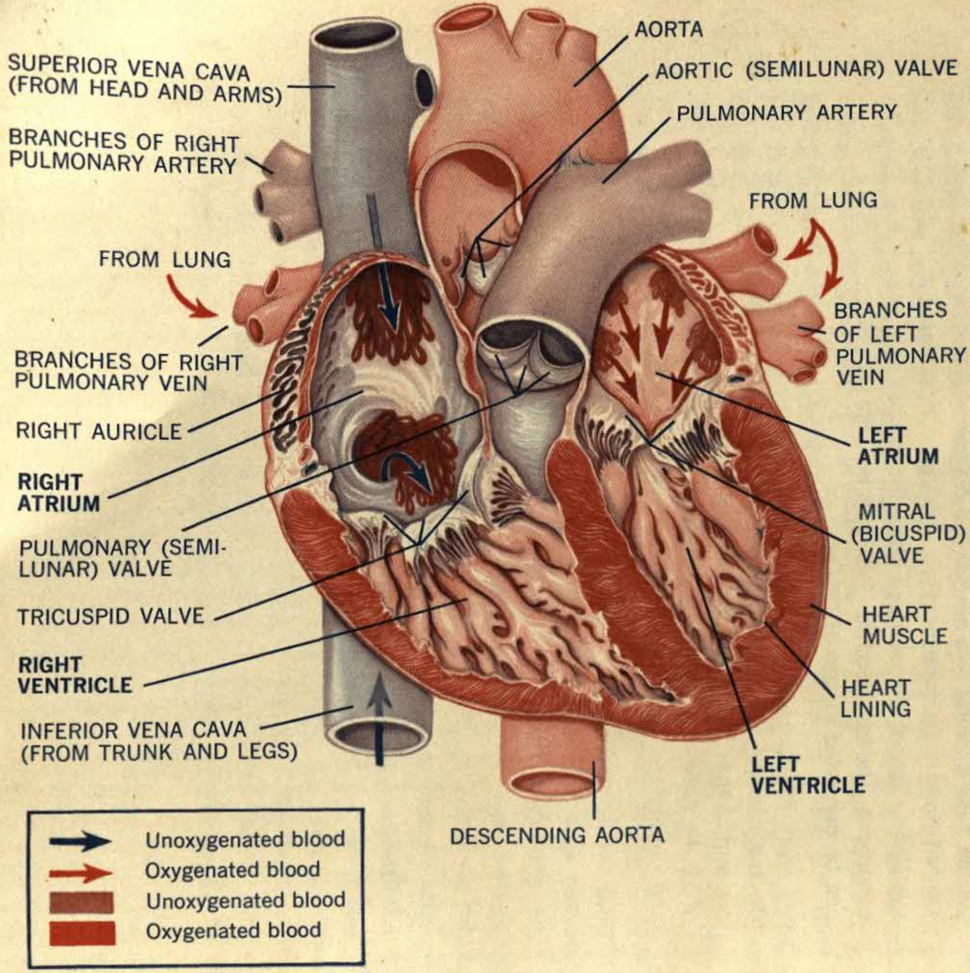
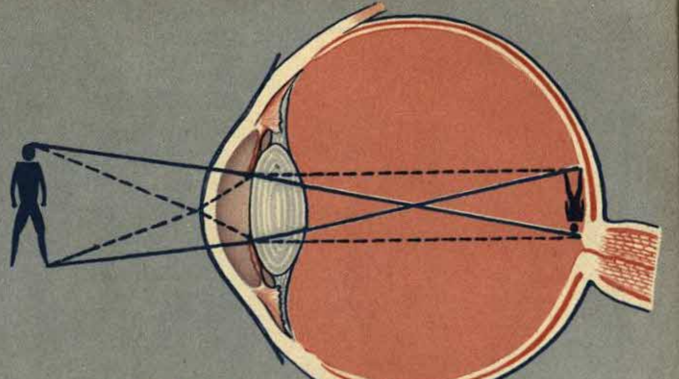
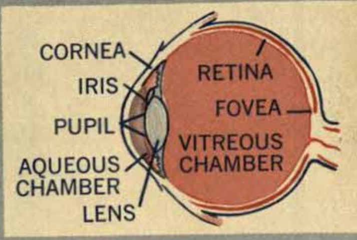


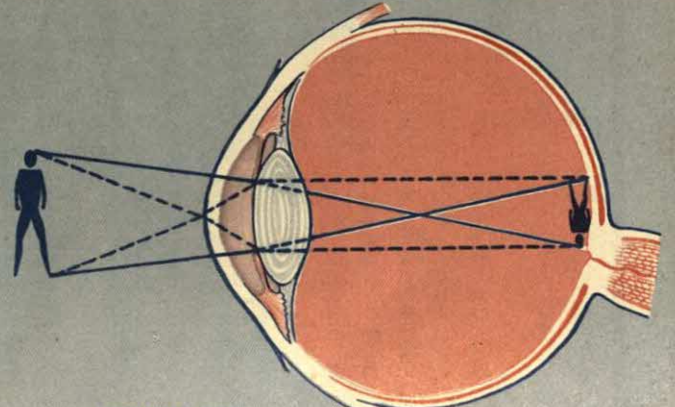
BASE

The heart has four chambers: the right atrium and ventricle and the left atrium and ventricle. There is no opening in the wall between the right and left sides of the heart, but there are openings (the bicuspid and tricuspid valves) between atrium and ventricle on each side. As the arrows indicate, blood enters the right atrium from the entire body with the exception of the lungs; blood enters the left atrium from the lungs. On the following transparent overlays, you will see how the muscles contract and valves open and shut to circulate the blood. Watch how the heart changes shape and size as this process takes place.



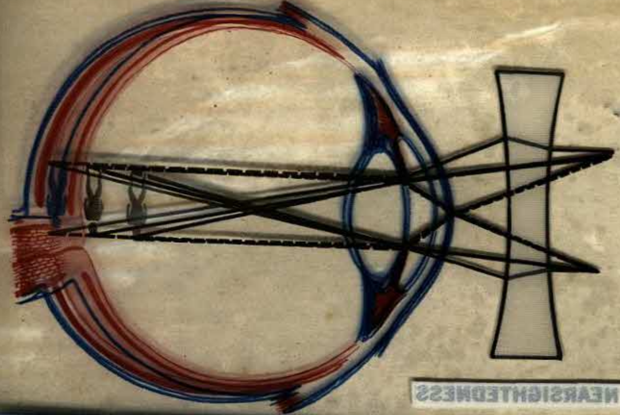
NORMAL EYE

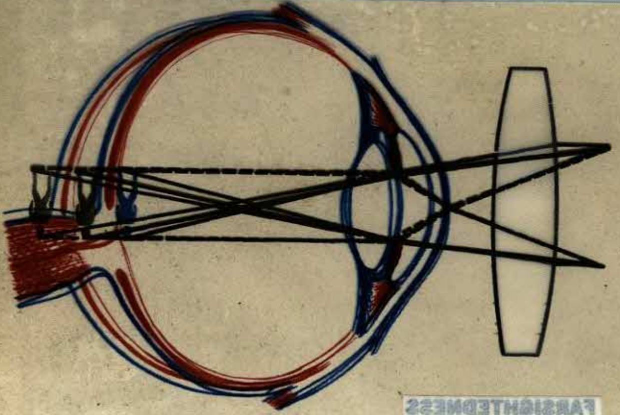


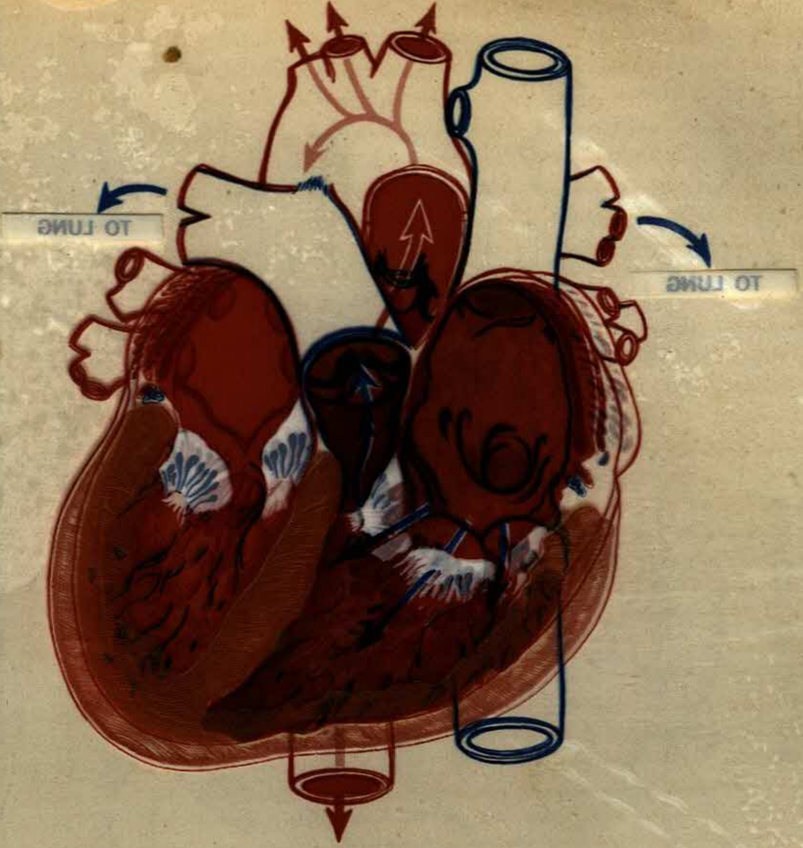


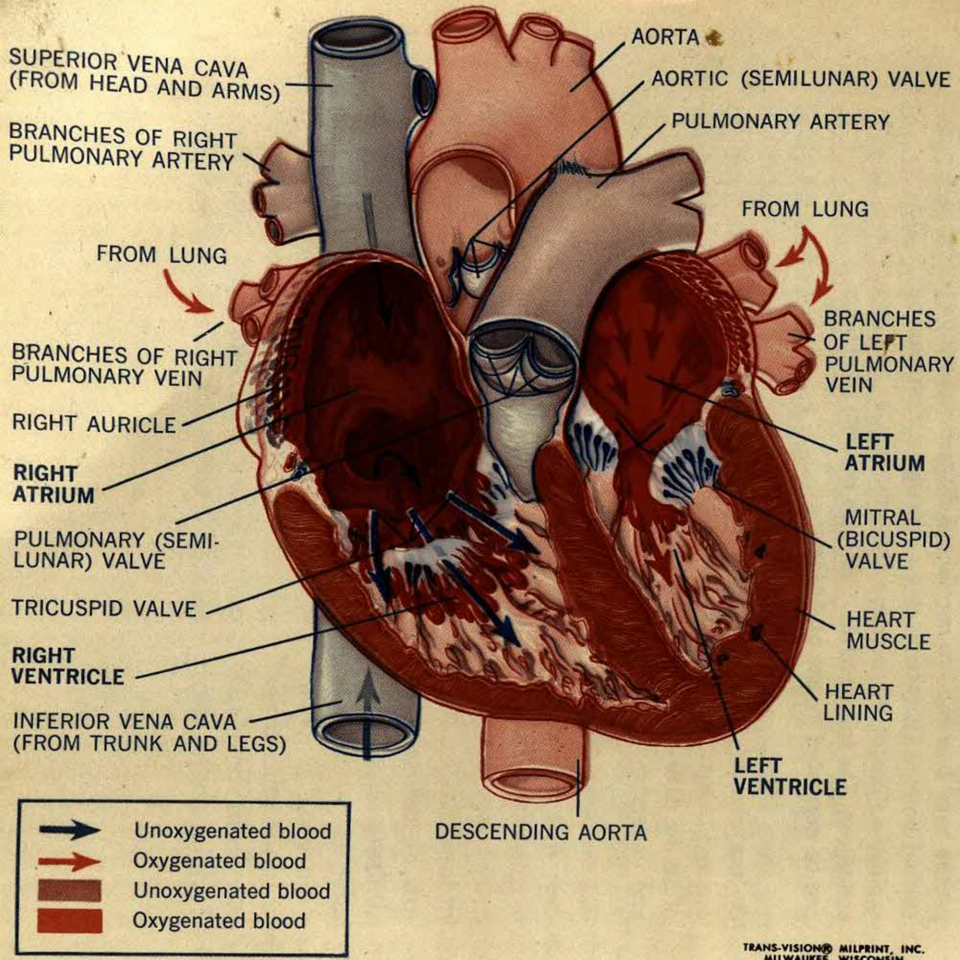
NORMAL EYE

Vision depends on the proper focus of light rays on the retina of the eye. In a normal eye, the size and shape of the eyeball and lens produce the proper focus. The light rays entering the eye are refracted, or bent, through the cornea and aqueous humor, the lens, and the vitreous humor. In a normal eye, the refracted rays converge on the fovea of the retina, where an inverted image is clearly formed.









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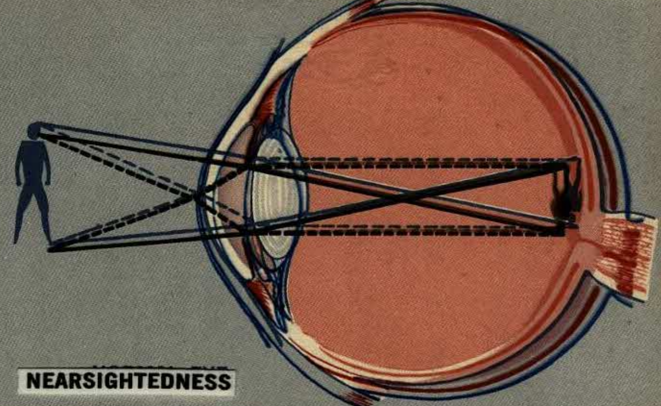
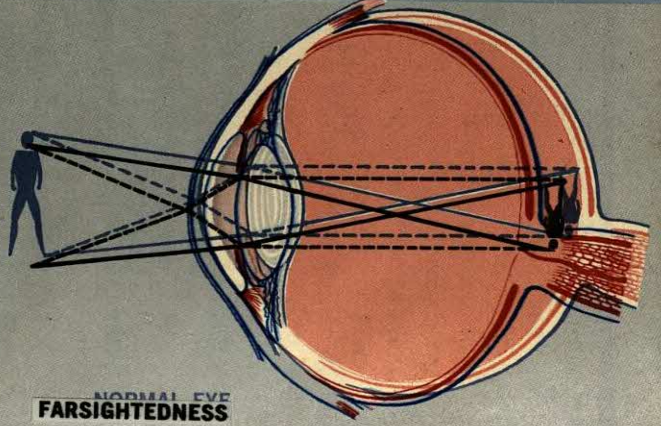
OVERLAY 1

Here both atria are filling with blood. An impulse in a specialized tissue in the right atrium starts automatic and rhythmical contractions. These contractions force open the valves leading to the ventricles and allow the blood to enter these chambers. Compare the shape of the four chambers at this stage of the heart beat with the shape of the heart in the base drawing.



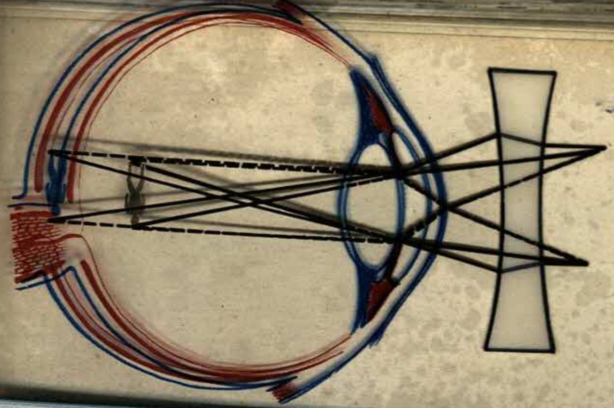
NEARSIGHTEDNESS

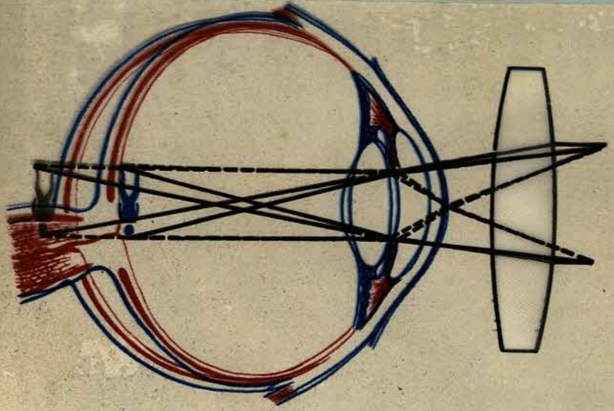
Nearsightedness, or myopia, is a condition of faulty vision in which refracted light rays converge in front of the retina because the eyeball is longer than normal from front to back. The image, shown in grey, is blurred for all objects seen at a distance. Objects seen close at hand may be clear.

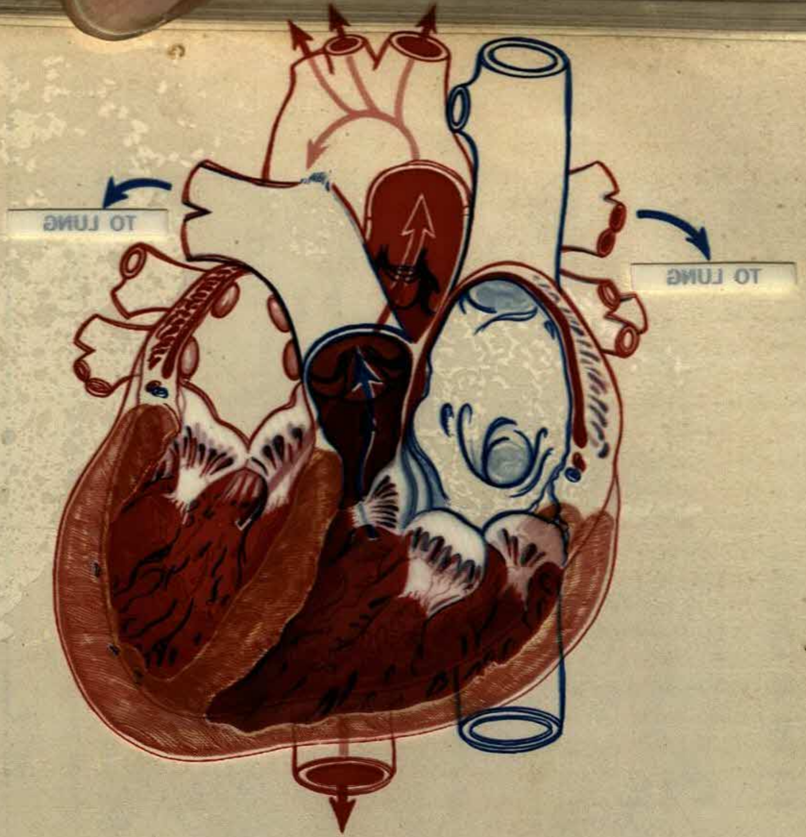


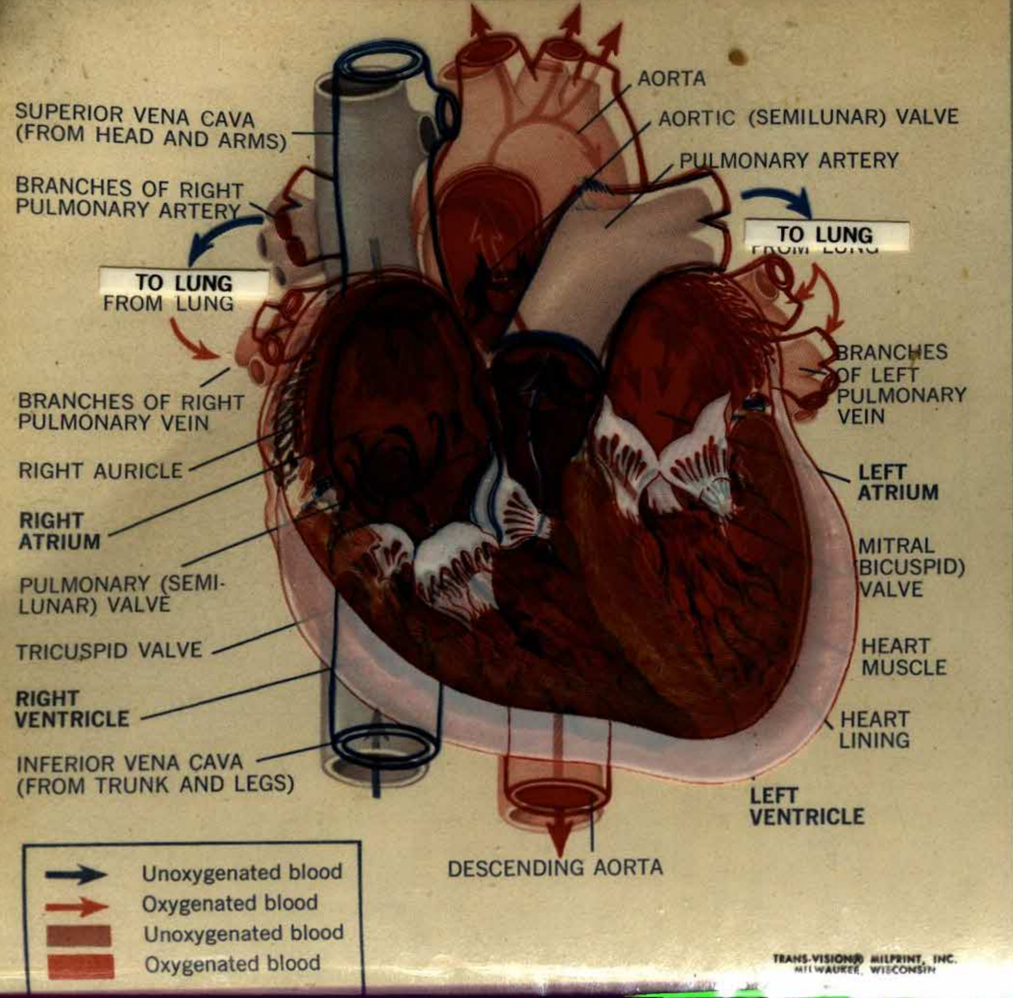
FARSIGHTEDNESS

Farsightedness, or hyperopia, is a condition of faulty vision in which refracted light rays converge behind the retina because the eyeball is shorter than normal from front to back. The image, shown in grey, is blurred for all objects viewed close at hand. Objects at a distance are seen clearly.









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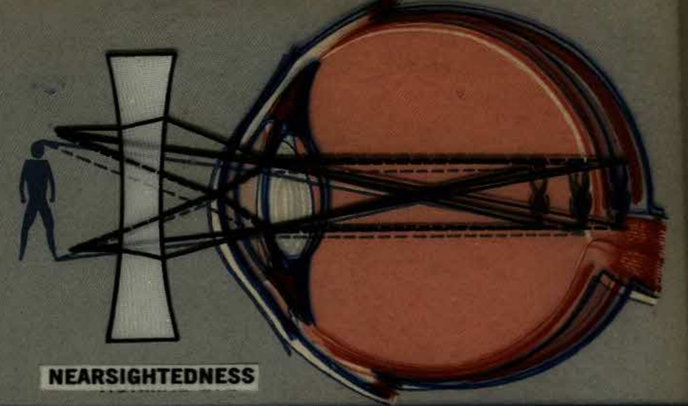
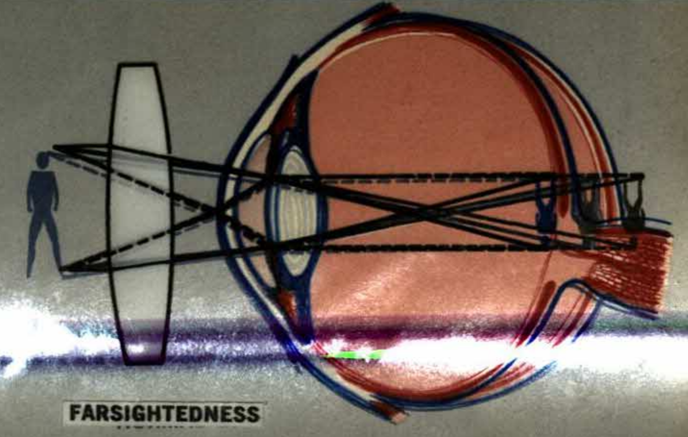
OVERLAY 3

Here the semilunar valves in the ventricles are opening and, as the arrows indicate, the blood is being forced from the right ventricle into the pulmonary artery and from the left ventricle into the aorta. From the pulmonary artery, the blood enters the lungs, where it picks up oxygen and then returns to the left atrium. From the aorta, the oxygenated blood enters the body. By studying all four drawings through the transparent overlays you can see the changes in the shapes of the chambers as blood circulates through them. The complicated process in each heart beat occurs about seventy-two times a minute.



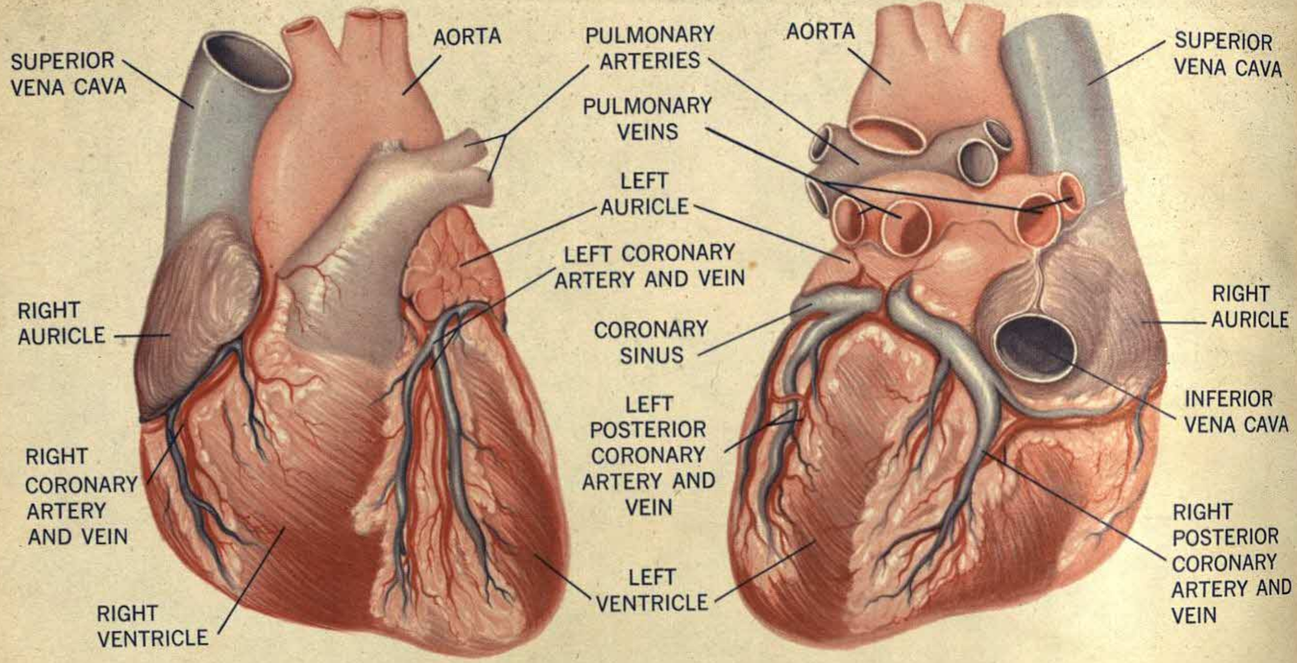
NEARSIGHTEDNESS

The refractive errors of nearsightedness can be corrected by a concave lens as shown above. The concave lens diverges the light rays from the objects so that they meet farther back in the eye. This brings the image to focus on the retina, and therefore vision is corrected.



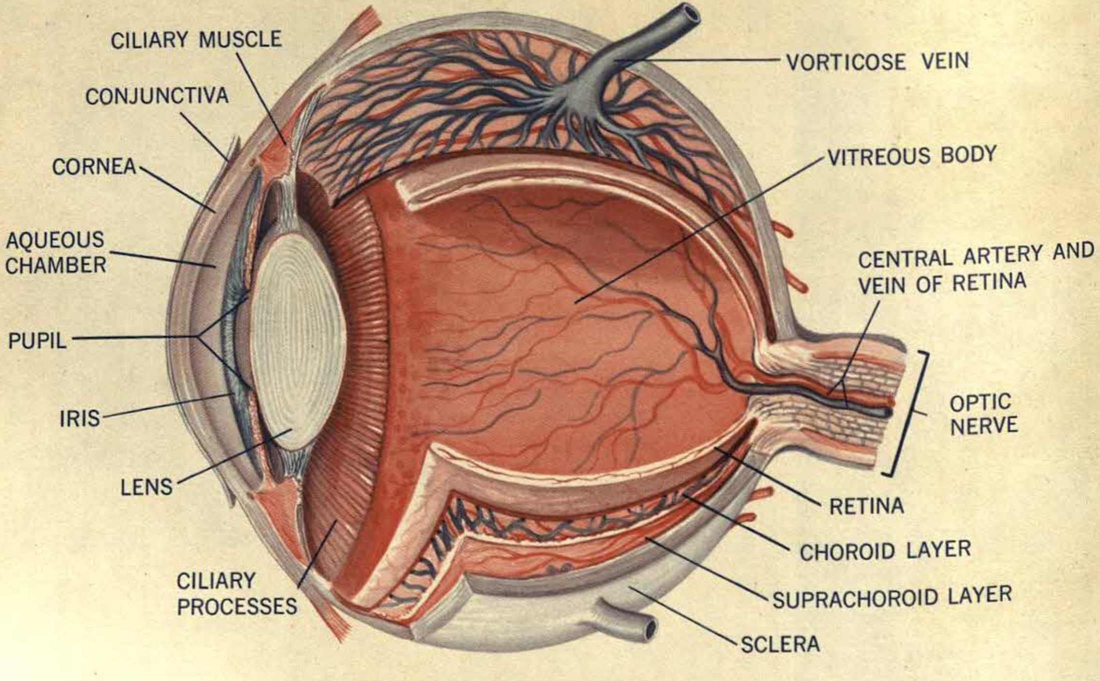
FARSIGHTEDNESS

The refractive errors of farsightedness can be corrected by a convex lens as shown above. The convex lens converges the light rays from the object to bring forward the point at which the rays meet, focusing the image on the retina. Vision is thereby corrected.

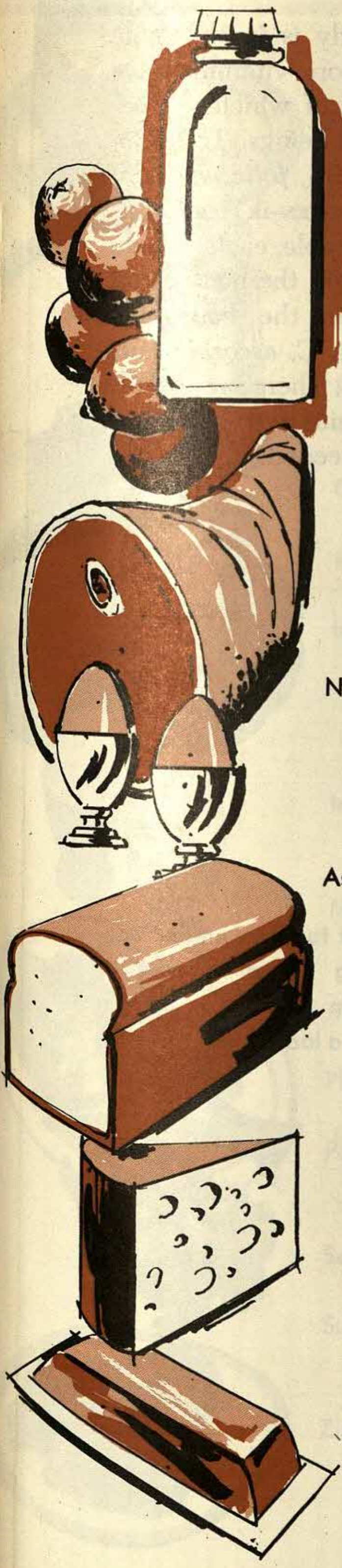


FRONT VIEW OF THE HEART

BACK VIEW OF THE HEART



ANATOMY OF THE EYE



Some Health Effects and Food Sources of Vitamins

Vitamin	*Some Health Effects*	*Some Food Sources*
A	Aids growth and vision; builds resistance to infection; prevents sore eyes and night blindness	Broccoli, carrots, chard, cod liver oil, peppers, spinach, sweet potatoes, butter or margarine, eggs
B_1 or Thiamin	Aids growth; stimulates appetite; essential for normal condition and functioning of nerve tissue; prevents beriberi	Bran, enriched bread,[1] whole grain, liver, lean meat, nuts, yeast
B_2 or Riboflavin	Improves growth; essential for proper functioning of nerve tissue; promotes good health	Enriched bread, broccoli, cheese, eggs, milk, lean meat, oysters, prunes, yeast
Niacin or Nicotinic Acid	Promotes growth and good health; maintains normal functioning of digestive system and skin; prevents pellagra	Bran, fish, heart, kidney, liver, lean meat, wheat, bread, milk, potatoes, spinach
C or Ascorbic Acid	Aids in development of good teeth; improves appetite; promotes growth; helps protect body from disease; prevents scurvy	Broccoli, citrus fruits, raw cabbage, cauliflower, peppers, pineapple, strawberries, tomatoes
D	Aids body in using calcium and phosphorus to build strong bones; prevents rickets	Irradiated foods such as milk and margarine; halibut liver oil, sardines, tuna, butter
E	Believed to be important in human reproduction	Cottonseed oil, corn oil, lettuce, peanut oil, meat, milk, and eggs
K	Aids in clotting of blood	Cabbage, cheese, cauliflower, spinach, liver, tomatoes

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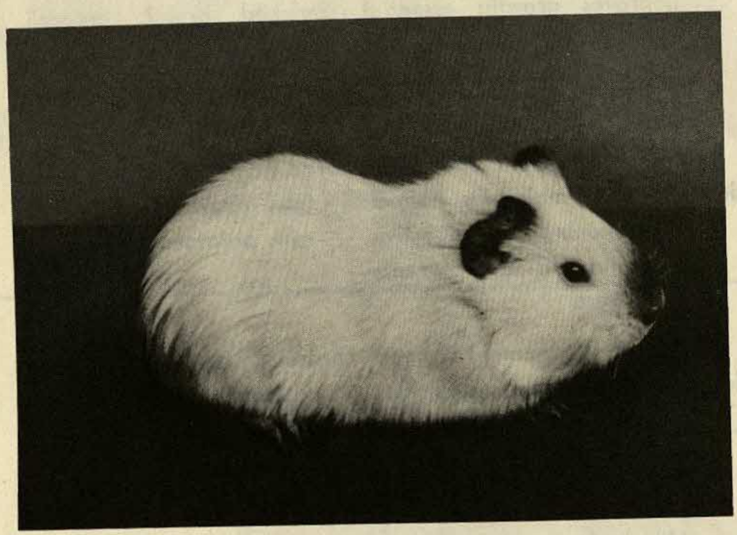
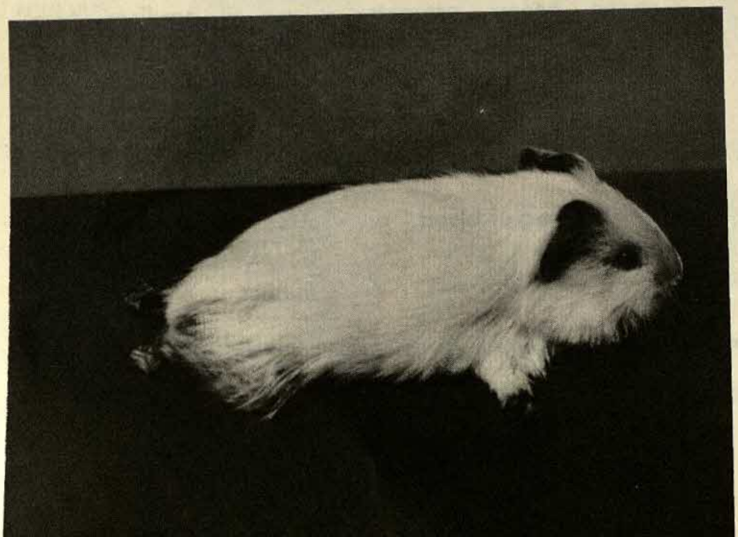
[1] Some breads and cereals which have B vitamins added are said to be *enriched*.

conducted many experiments with living things to see if the chemicals acted like vitamins. They have studied the molecules of the new vitamins to see how they are put together. They have then tried to find out just how the vitamins enter into the complicated chemical reactions in protoplasm. Bacteria have been used in many of their studies. What would be the advantage of using bacteria in such studies?

Information about some of the vitamins that are considered necessary to keep your body operating properly is in the table on page 489. Many more vitamins have been discovered, some of which are believed to affect human beings. These include vitamin B_6 and B_{12}, ***folic acid*** and ***pantothenic*** (pan-tuh-THEN-ik) ***acid.*** As you will note from the table, each vitamin has a definite effect upon the body. Most vitamins are stored in the body, but others, such as vitamin C, ***ascorbic*** (uh-SKOR-bik) ***acid,*** are not. Therefore, a daily supply of those vitamins which are not stored in the body is needed.



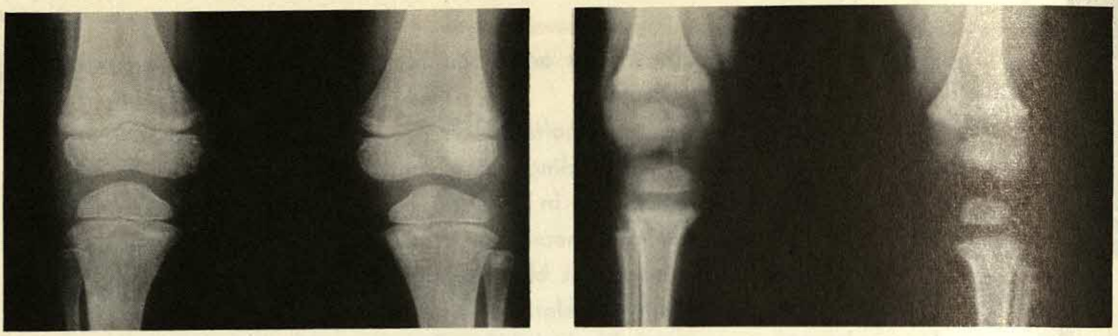
Courtesy Mary Swartz Rose



Rat at top lives on diet containing normal amount of vitamin C; rat at bottom shows a lack of it.

Some Health Effects and Food Sources of Mineral Elements

Mineral Elements	*Some Health Effects*	*Some Food Sources*
Calcium	Used in building bones and teeth; aids in proper functioning of heart, nerve, and muscle; aids blood clotting	Bread, broccoli, cauliflower, cheese, ice cream, milk, beans, peas, carrots, cabbage, egg, shellfish, turnips
Chlorine	Forms hydrochloric acid in the stomach, which helps digest proteins	Bread, cheese, clams, crackers, ham, pretzels, sauerkraut, eggs, milk, salt
Cobalt	Aids growth, appetite, condition of skin, production of red corpuscles	Liver, seafoods, leafy vegetables, whole grains
Copper	Essential in formation of hemoglobin and in stimulating growth of red blood cells; helps prevent anemia	Liver, mushrooms, shellfish, bran, bread, eggs, meat, nuts, oatmeal, leafy vegetables
Iodine	Essential in normal functioning of thyroid gland; protects from goiter	Cod liver oil, salt-water fish, iodized salt, vegetables, cereals, dairy products and fruits produced on soils of good iodine content
Iron	Essential in formation of hemoglobin	Apricots, egg yolk, heart, liver, kidney, bananas, oatmeal, potatoes, raisins
Magnesium	Important for muscle activity, bone structure, and nerve functioning	Beans, Brussels sprouts, clams, nuts, peas, spinach, beef, milk, potatoes
Manganese	Essential for normal growth	Bananas, beets, celery, dates, liver, oatmeal, tomatoes
Phosphorus	Essential in building bones and teeth	Bran, cheese, egg yolk, grains, meat, milk, and shellfish
Potassium	Essential for normal growth	Cheese, eggs, liver, macaroni, milk, nuts, oatmeal, seafoods, prunes, raisins
Sodium	Regulates water content of cells	Bread, clams, crackers, oysters, whole grains, milk, salt
Sulfur	Required for the formation of body proteins used in building and repairing tissues	Cheese, eggs, lean meat, shellfish, bread, milk
Zinc	Required for normal growth and development of hair	Beans, liver, oysters, spinach, beets, potatoes



The Children's Hospital Medical Center—Boston

When calcium and vitamins are lacking or insufficient in a child's diet, child may develop rickets. Compare the bones at left, which have developed normally, with those affected by rickets, right.

Minerals for Health

When food such as meat, potatoes, or bread is completely burned, only a powdery ash, consisting of the minerals that were in the food, remains. Certain chemical elements from these minerals are necessary to the body if it is to operate properly. The table on page 491, which lists their uses in the body and the foods from which they can be obtained, should be carefully studied. For example, calcium is needed in building bones and teeth. Growing young people especially need this element, an excellent source of which is milk. A lack of iodine to make the thyroid gland function properly causes a disease known as *goiter.* Iron helps in the formation of essential hemoglobin. As the table shows, each element has a special job to do.

Water for Life

By now, you have probably recognized the importance of water to the body. Three-fourths of the soft tissue of the body is composed of water. None of the life processes of the body can take place without water. Food must be mixed with water before it can be digested, and digested food must be dissolved in water before it can be transported to cells by the blood.

Water is the basic fluid of blood and lymph. It aids in carrying red blood cells with their loads of oxygen through the blood vessels of the body.

Oxygen enters cells of the body through a water medium, and waste materials are given off through it.

In what other ways, besides those just discussed, is water necessary for life? In making your list, consider all living things—both plants and animals.

You obtain a good deal of water in the food you eat. How could you use the table on page 485 to estimate the amount of water you might obtain from one meal without drinking any water at all?

MEETING YOUR FOOD NEEDS

You are probably beginning to wonder how it is possible for a person to obtain the nutrients necessary to keep the body operating properly. It is not difficult. Examine the Food Sources column in the tables on pages 489 and 491. Note in how many different types of food the essential nutrients are to be found.

Balanced Diet

When the day's meals are planned to include all the nutrients in the amounts needed for good health, it may be said that you are obtaining a ***balanced diet.*** To help you select a balanced diet, food scientists, called ***nutritionists,*** recommend that some foods from each of the four food groups shown on this page be selected each day in the amounts shown. Everyone concerned about good health should check his diet frequently against these basic four food groups.

THE FOUR FOOD GROUPS

Milk Group

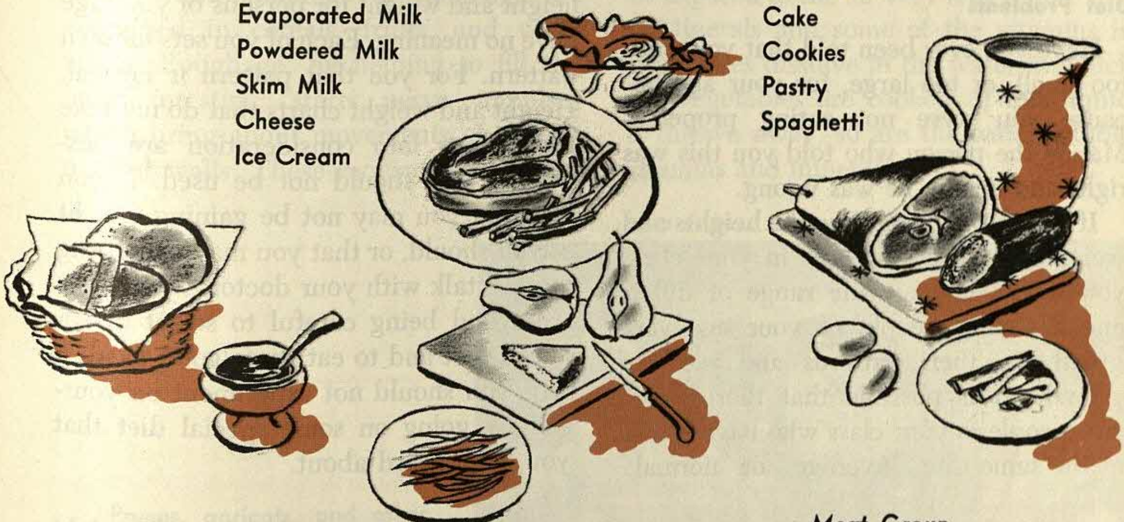
You need about a quart of milk a day.

- **Whole Fresh Milk**
- **Evaporated Milk**
- **Powdered Milk**
- **Skim Milk**
- **Cheese**
- **Ice Cream**

Bread—Cereal Group

You need four or more servings a day.

- **Enriched Bread**
- **Whole-Grain Cereals**
- **Cake**
- **Cookies**
- **Pastry**
- **Spaghetti**



Vegetable—Fruit Group

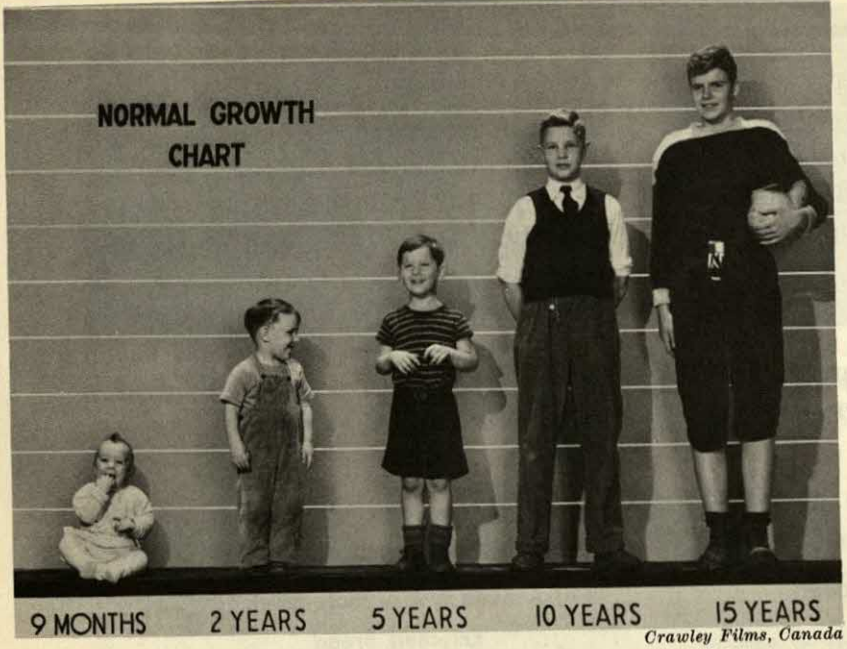
You need four or more servings a day.

- **Citrus Fruits**
- **Green Vegetables**
- **Yellow Vegetables**
- **Potatoes**
- **Other Vegetables and Fruit**

Meat Group

You need two or more servings a day.

- **Beef**
- **Veal**
- **Pork**
- **Lamb**
- **Poultry**
- **Fish**
- **Shellfish**
- **Eggs**
- **Nuts**
- **Dried Peas and Beans**
- **Game**



Crawley Films, Canada

Normal growth pattern of boy, from age nine months to fifteen years, is shown on the chart at left.

Diet Problems

Have you ever been told that you were too small, or too large, for your age because you were not eating properly? Maybe the person who told you this was right and maybe he was wrong.

If you were to compare the heights and weights of boys and girls in your class, you would find a wide range of differences. Young people of your age vary greatly in their patterns and rates of growth. It is possible that there aren't two people in your class who have grown at the same rate. "Average," or "normal," height and weight for persons of your age have no meaning. Each of you sets his own pattern. For you that pattern is normal. Height and weight charts that do not take these facts into consideration are misleading and should not be used. If you feel that you may not be gaining weight as you should, or that you may be getting too fat, talk with your doctor.

Beyond being careful to select a balanced diet and to eat three good meals a day, you should not experiment on yourself by going on some special diet that you have heard about.

In Terms of Body Weight

	Calories per lb. per day	
Age in Years	*Boys*	*Girls*
13–15	30–31	24–29
16–20		
Very active	35	25
Moderately active	27	20
Inactive	18	17

If you can get height and weight data covering the past several years for class members, you can make some interesting comparisons. Each person can make a graph to show his change in height and another graph to show his change in weight. When you make such graphs, all persons should use the same scale. Why?

Persons who tire easily may not be eating enough food to supply the amount of energy needed to carry on their activities, or their diet may lack essential minerals and vitamins.

Some people are very sensitive, or ***allergic***, to certain types of food, which may make them quite ill, or may cause a rash to form on their bodies. In such cases, the diet has to be carefully checked by a doctor to determine what food is causing the difficulty.

Constipation may indicate that there is not sufficient ***roughage*** and other materials in the diet. Roughage is the indigestible plant fiber which passes through the digestive system into the large intestine. Considerable amounts of roughage are contained in cereals, fruits, and vegetables. Roughage, by helping to fill the large intestine, starts nerve impulses which bring about movements of the intestinal walls. These movements help to eliminate intestinal wastes. On the other hand, too much roughage may irritate the lining of the intestine and thus be harmful. Such foods as orange juice and prunes contain substances other than roughage, which aid in intestinal movements.

Preservation of Vitamins and Minerals

Some vitamins in foods may be destroyed when food is exposed to air. Vitamin C, for example, combines with oxygen, or oxidizes, when exposed to the air, and forms a new chemical compound of no value to the body. Fresh vegetables should, therefore, be kept cool and covered to prevent loss of precious vitamins. Peeled fruits and vegetables should not be exposed to the air very long before use.

Minerals and some of the vitamins in vegetables dissolve in the water in which the vegetables are cooked. If this liquid is thrown away, so are the water-soluble vitamins and minerals.

California Dried Fruit Research Institute

Prunes, apricots, and other dried fruits make excellent breakfast foods, but they can also be combined to make tasty deserts for lunch.

Other vitamins are destroyed when kept at high temperatures for long periods. In general, foods should be cooked in a small amount of water, at the lowest possible temperature, for as short a time as possible, and with the least surface exposure to the air.

Considerable amounts of vitamin B_1, or thiamin, may be destroyed when some canned foods are heated to high temperatures to preserve them. Vitamins are not readily destroyed by low temperatures, and properly frozen foods retain most of their vitamins. Dehydration, or drying, of foods usually destroys more vitamins than any other method of food preservation.

A knowledge of all these food facts should help you place proper value on food advertisements. Some of them are really informative, but others are misleading. If a person thinks he needs vitamins or minerals in addition to those he obtains from a well-balanced diet, he should consult his physician rather than buy preparations that are claimed, in advertisements, to be "good for him."

Eating Habits

The way a person eats, the amount of food he eats at one time, the number of times a day he eats, and the conditions under which he eats have an effect upon the proper functioning of the body.

You have seen why thorough chewing of food, or ***mastication*** (mass-tih-KAY-shun) is important. To chew well, it is necessary to avoid filling the mouth too full, or eating too rapidly.

Eating too much at one time is also a bad practice. Overfilling the stomach may result in indigestion.

Eating between meals may be undesirable for several reasons. It may add unnecessary fat to the body. It may lessen the appetite for food at regular mealtimes and thus prevent you from eating enough wholesome food. Candy or other "sweets" generally eaten between meals may supply energy for the body, but they contain few of the essential vitamins. They encourage decay of the teeth.

It has been demonstrated that excitement, fear, worry, and anger interfere with digestion. Therefore, you should not eat when you are in any of these emotional conditions.

Food Misconceptions

Whenever people believe something that is not true, it is said that they have a ***misconception.*** There are many misconceptions about the effects of different kinds of food on the body. If you are thinking scientifically, you will hesitate to accept statements that cannot be supported by facts.

Make a list of statements about food which you have heard and which you think may be misconceptions. Compare your list with lists prepared by other members of your class. Which ones actually are misconceptions? How can you make sure? How do you suppose these statements got into circulation?

EXERCISE AND REST

Exercise is necessary for the proper development and nerve control of muscles. Through frequent exercise, the baby

High-jumping is a strenuous activity, but there are many milder forms of exercise which will help to develop good muscular control and improve blood circulation.

Hays from Monkmeyer

learns to control his muscles so that he can walk without wobbling. Athletes and dancers exercise their muscles for a long time before they develop the strength, skill, and endurance they need to be outstanding performers.

Physical activity develops strong heart muscles and good circulation. Proper development of the lungs is also dependent upon activities which exercise the muscles of breathing. Exercise helps develop an appetite and aids in eliminating wastes from the body. It also helps the body to relax and to overcome nervous fatigue from mental activity. Exercise improves posture by strengthening muscles across the abdomen, shoulders, and back.

Periods of rest and sleep are most essential in keeping the body and mind operating properly. They are particularly important during childhood and adolescence to ensure healthy growth. Tiredness, or ***fatigue,*** results when muscle and nerve cells are active. During rest, the tissues which have been strained are repaired, and new supplies of food are stored in them. During very vigorous physical exercise, the chemicals produced in the muscles by exertion accumulate faster than they can be removed by the circulation and by breathing. Exhaustion forces the person to stop exercising, and he keeps panting for several minutes afterwards.

Athletes and coaches have found that the way to build strength and endurance is by increasing exercise gradually on a very regular schedule.

Here is a way in which you can demonstrate muscle fatigue. Place your hand palm down on top of your desk. Then tap with your forefinger as rapidly as you can. Keep tapping your finger as long as you can. You'll find that, after several minutes, your muscles temporarily stop working.

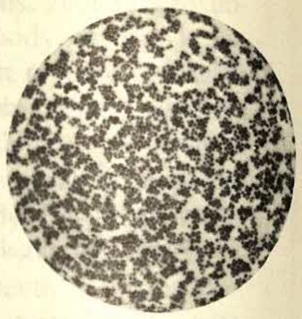
Why is it that the muscle of your heart doesn't get tired and stop in the same way that the muscles of your hand did?

DISEASE GERMS

American Museum of Natural History

Medicine Bundle

General Biological Supply House



Staphylococcus aureus

DISCOVERIES ABOUT DISEASES

Before the real causes of diseases were understood, people did many peculiar things to prevent themselves from becoming ill, or to cure themselves after they had become ill. Early man believed that such a dreadful experience as an illness could be caused only by evil spirits getting into his body.

Early Cures

Special ornaments, called ***charms,*** were generally worn to ward off evil spirits. But if a person did become ill, attempts were made to drive out the evil spirits by beating drums and making weird noises. Or hot needles and other sharp objects were used to make holes in the body so that the evil spirits could escape.

Later, it was believed that disease was caused by an overproduction in the body of a substance called ***black bile.*** Attempts were then made to remove this substance from the body.

During another period, outdoor night air was accepted as being responsible for certain diseases. People kept their windows and doors tightly shut to prevent it from getting into their houses.

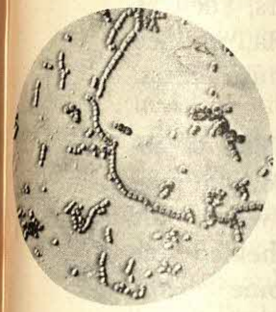
Some people today are still influenced by many of these old beliefs regarding the causes of disease. They wear good-luck charms and other ornaments to ward off illness, or they shut out the night air which they believe is not healthy.

Today, knocking on wood is a rather common practice for some people. When someone asks them how they feel, they may reply by saying, "fine," and then they knock on wood. How do you suppose this practice got started? Do the people who knock on wood really believe it will keep them from getting sick? If not, why do they do it?

Causes of Some Diseases

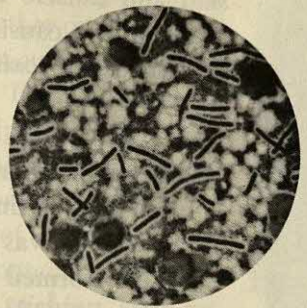
Causes of a number of diseases have been found by carefully controlled experimentation. Even though there had

General Biological Supply House



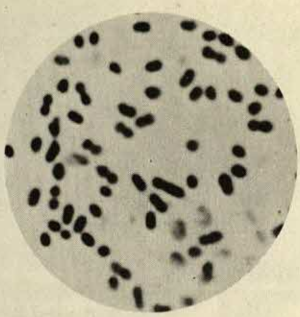
Streptococcus pyogenes

General Biological Supply House



Bacillus anthracis

Chas. Pfizer & Co., Inc.



Pneumococci

been many explanations regarding the causes of diseases, some scientists doubted them. They wanted facts which could be proved by experimentation. Among these early scientists were Pasteur and Koch. Pasteur proved that a certain ***organism*** caused a silkworm disease. Koch discovered the organism causing anthrax, a disease which had been killing many livestock and some people. The organisms causing these diseases were so small that a microscope had to be used to see them. For this reason, they are often called disease-producing ***microörganisms.*** They are also commonly called disease ***germs.***

Koch worked out a system, or method, which he said must be used in order to prove that a certain germ caused a certain disease. This is it.

1. The germ must be found in every animal that had the disease.

2. Germs from the sick animal must be identified with a microscope and grown in nutrient media.

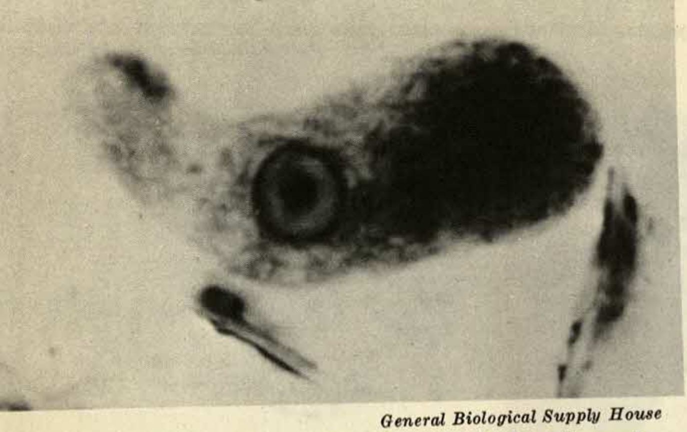
3. These germs must then be injected into healthy animals and the animals must then get the disease.

4. Germs taken from this sick animal must be the same as those identified in step 2 above.

After it was proved that anthrax and silkworm disease were caused by germs, scientists began to suspect that other diseases, especially some of those afflicting man, might also be caused by germs. Although a number of diseases were found to be caused by microörganisms, some have other causes. You have already learned that an improper diet may cause some. Later you shall see that diseases of a different kind may occur when organs of the body fail to function properly.

Disease-Producing Organisms

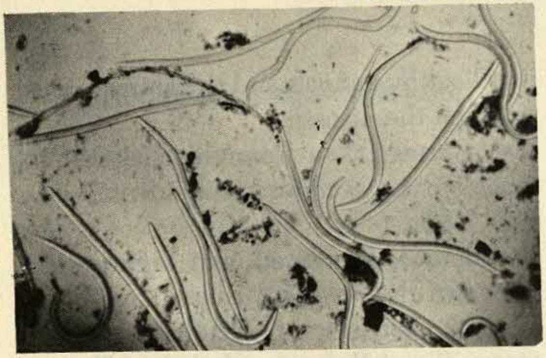
Different types of bacteria have been found to be the cause of diphtheria, typhoid fever, some kinds of pneumonia, tuberculosis, boils, one type of dysentery, and undulant fever. Some of these act by destroying tissues. In tuberculosis, it may



General Biological Supply House

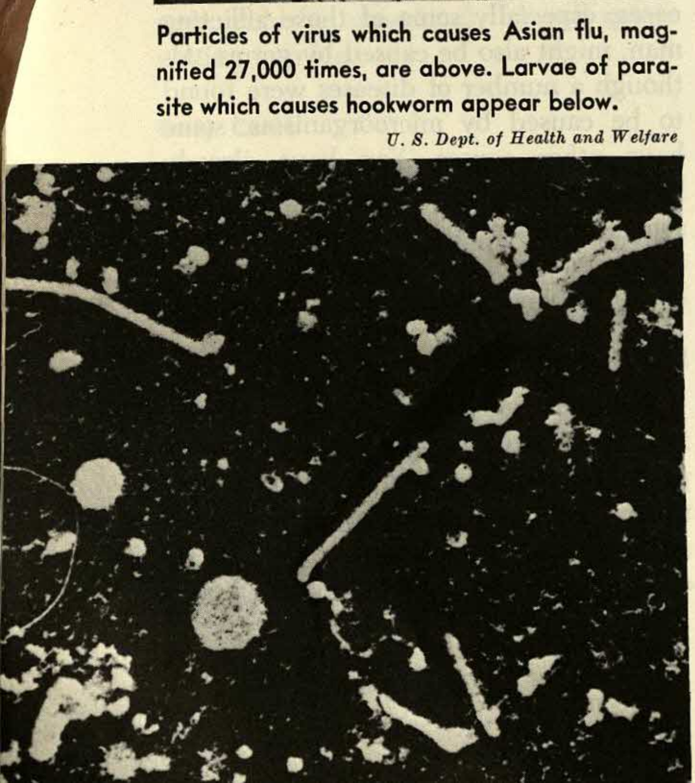
Protozoan parasite, above, called endamoeba histolytica, causes amoebic dysentery in man.

Walter Reed Institute



Particles of virus which causes Asian flu, magnified 27,000 times, are above. Larvae of parasite which causes hookworm appear below.

U. S. Dept. of Health and Welfare



be lung tissue; in boils and abscesses, the skin and muscle tissue. Others, such as the organism causing diphtheria, produce poisons called ***toxins,*** which cause illness.

Have you ever had a boil or abscess on your body? If so, you may be able to find where it was by the scar that was left after it healed. The scar formed because some of the tissue was destroyed by bacteria.

A fungus causes athlete's foot and ringworm by destroying skin cells and releasing a substance that irritates the skin.

Protozoa are organisms considerably larger than bacteria. Malaria is caused by a protozoan. The protozoan which causes malaria also produces a poison. Other protozoa cause sleeping sickness and a second type of dysentery.

Some disease-producers, ***viruses,*** are too small to be seen with an ordinary microscope. For this reason, they were not discovered by scientists for a long time. They are so small that they can pass through the membranes of body cells and, unlike many other germs, they cannot grow outside of living cells. Pictures have been made of some of these viruses by using an electron miscroscope. Measles, mumps, fever blisters, and chicken pox, smallpox, rabies, the common cold, influenza, and infantile paralysis are some common diseases caused by viruses.

Harmful Animals and Plants

Not all organisms causing disease are microörganisms. There are a number of worms that live in the human body as

parasites. A parasite is any organism entirely dependent on another organism.

Hookworm disease occurs in the warm moist sections of the United States. It causes anemia and fatigue. The eggs are deposited on the ground in human waste when sanitary outhouses or toilets are not used. The parasites get into the body when people go barefooted in these regions. Pork worm, or ***trichina*** (trih-KY-nuh), enters the body when pork, which is not sufficiently cooked, is eaten. It may cause a severe infection.

Some animals, such as certain snakes and spiders, inject a poisonous substance into the human body when they bite it.

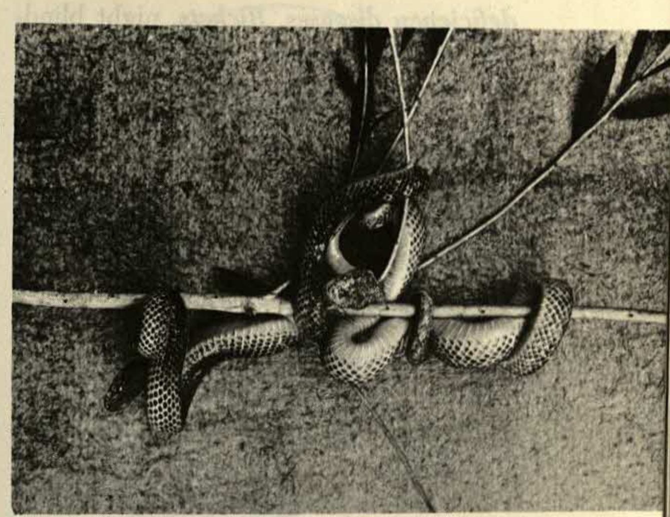
It is difficult to imagine that flowers cause illness, yet their pollen can produce a condition in some people which brings on allergies such as hay fever and asthma.

Certain poisonous mushrooms and plants cause serious illness when they are eaten. Other plants, such as poison ivy, poison oak, and poison sumac contain oily substances which irritate the skin when people touch them.

Find out how many members of your class get hay fever or asthma from pollen. Do any other members of their family have these allergies? Because they run in families, the tendency to allergies is believed inherited.

Deficiency Diseases

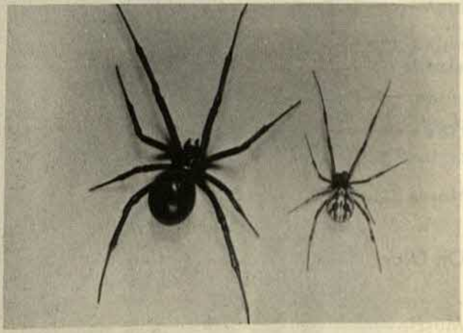
Although many human diseases have been found to be caused by living organisms, some diseases have other causes. A lack of vitamins in the diet, as you can see from the table on page 489, causes



American Museum of Natural History

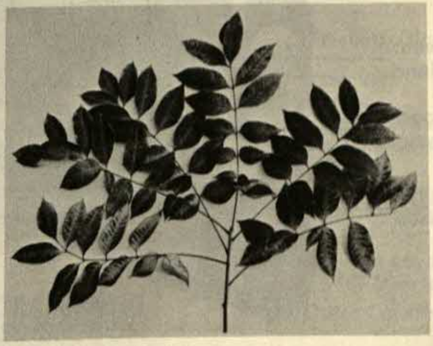
Snakes, such as viper, above, inject a poison into blood when they attack man. Bite of the black widow spider, below, is also poisonous.

U. S. Department of Agriculture



Sap of the poison sumac, below, irritates skin.

U. S. Department of Agriculture



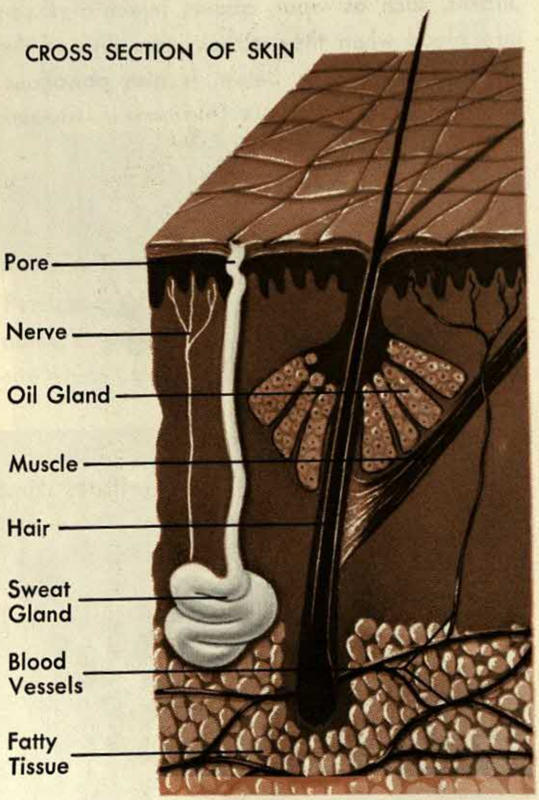
deficiency diseases. Rickets, night blindness, ***pellagra, scurvy,*** and ***beriberi*** are examples of such diseases. In rickets, the bones become soft. In pellagra, the skin becomes rough and the mouth sore, while in scurvy, the gums bleed and your bones pain you. Beriberi is a disease of the nervous system.

Diseases of Organs and Tissues

As you will recall, an improper functioning of certain tissues or organs of the body may also cause different kinds of illnesses.

As you may recall when the islands of Langerhans in the pancreas gland cannot produce enough of the hormone insulin, the body does not use sugar properly, and a disease known as diabetes occurs.

CROSS SECTION OF SKIN



One of the causes of anemia is the failure of the bone marrow to produce sufficient red blood corpuscles.

Cancer occurs mostly in older people when a group of cells begins to multiply very rapidly and in a disorderly way. As they multiply, they grow into surrounding tissues and make the person weak and sick. Why groups of cells should begin to grow in this manner is not yet understood.

When you hear of all the kinds of diseases there are, it makes you thankful that most people are healthy most of the time.

OUTER DEFENSES OF THE BODY

It is possible to avoid some illnesses and to cure others, as you shall learn later in this problem. But you live in a world where it is impossible to escape from harmful organisms. If the body were not able to protect itself, these organisms would soon get the better of all of you. The fact that there are over two billion people on earth today would indicate that the body possesses some kind of effective protection. How do these protectors operate?

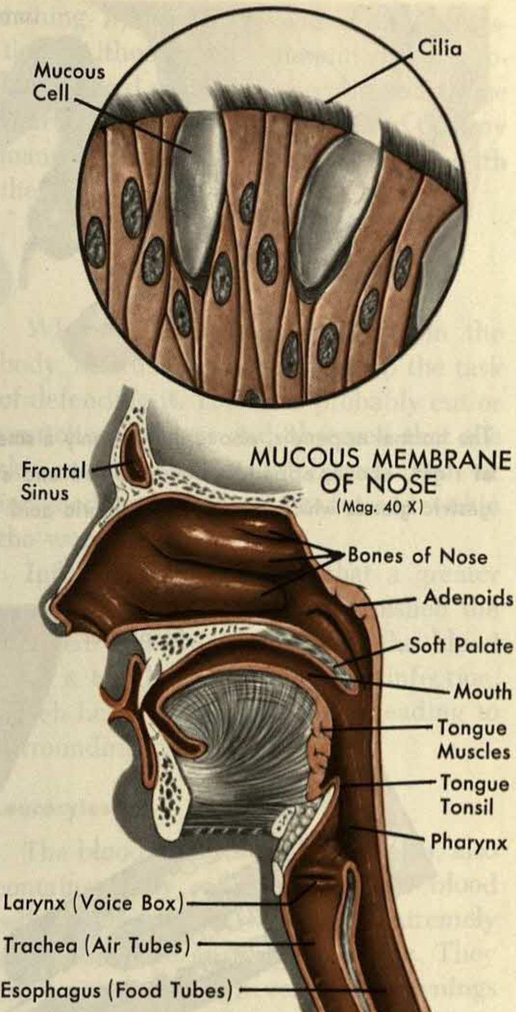
Outer Covering and Inner Lining

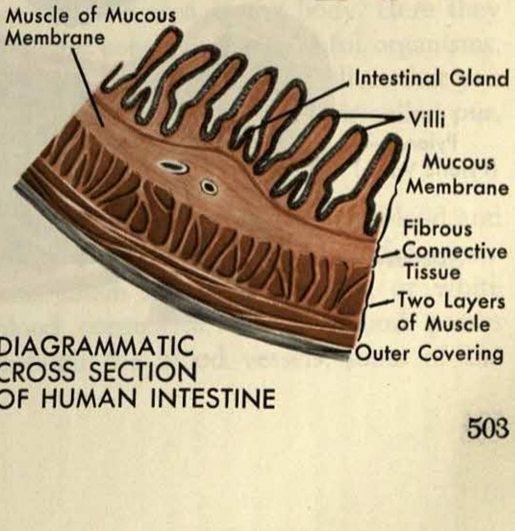
Look at the diagram of the skin on this page. Note the compact, tough layer of dead epithelial cells that form the outer layer of the skin. This prevents most harmful bacteria and other small particles from getting into the more delicate tissues underneath the skin.

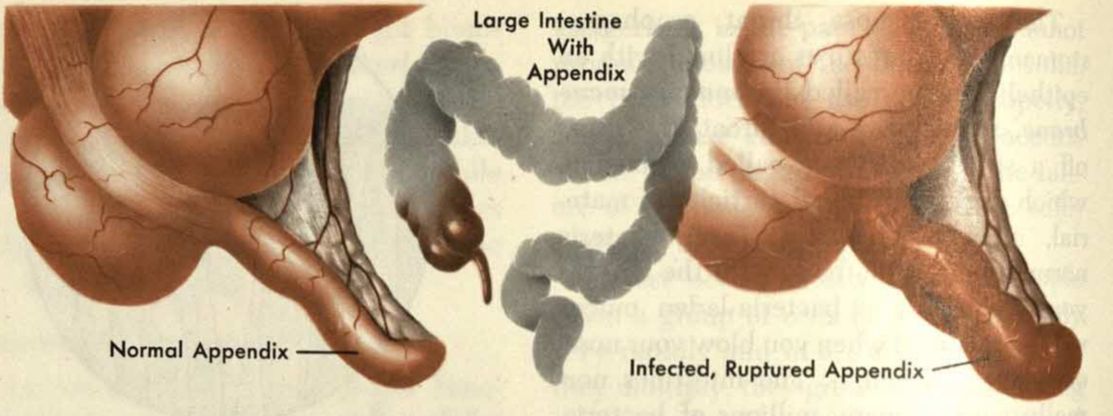
The mouth, nose, throat, esophagus, stomach, and intestines are lined with an epithelial tissue called the ***mucous membrane.*** In the nose and throat, this gives off a sticky substance called ***mucus,*** to which stick many small particles of material, including bacteria. These bacteria normally enter the body with the air that you breathe. The bacteria-laden mucus will be removed when you blow your nose, or when you cough. The intestines normally contain many millions of bacteria, but the epithelial lining usually prevents them from entering the blood and body tissues.

If the protective covering of the body is broken, harmful organisms can enter the body tissues. When this occurs, the tissue is said to be ***infected.*** Infections through skin wounds such as scratches, cuts, blisters, burns, or insect bites are rather common. Less common is infection in the intestines caused when harmful germs succeed in invading the epithelial lining.

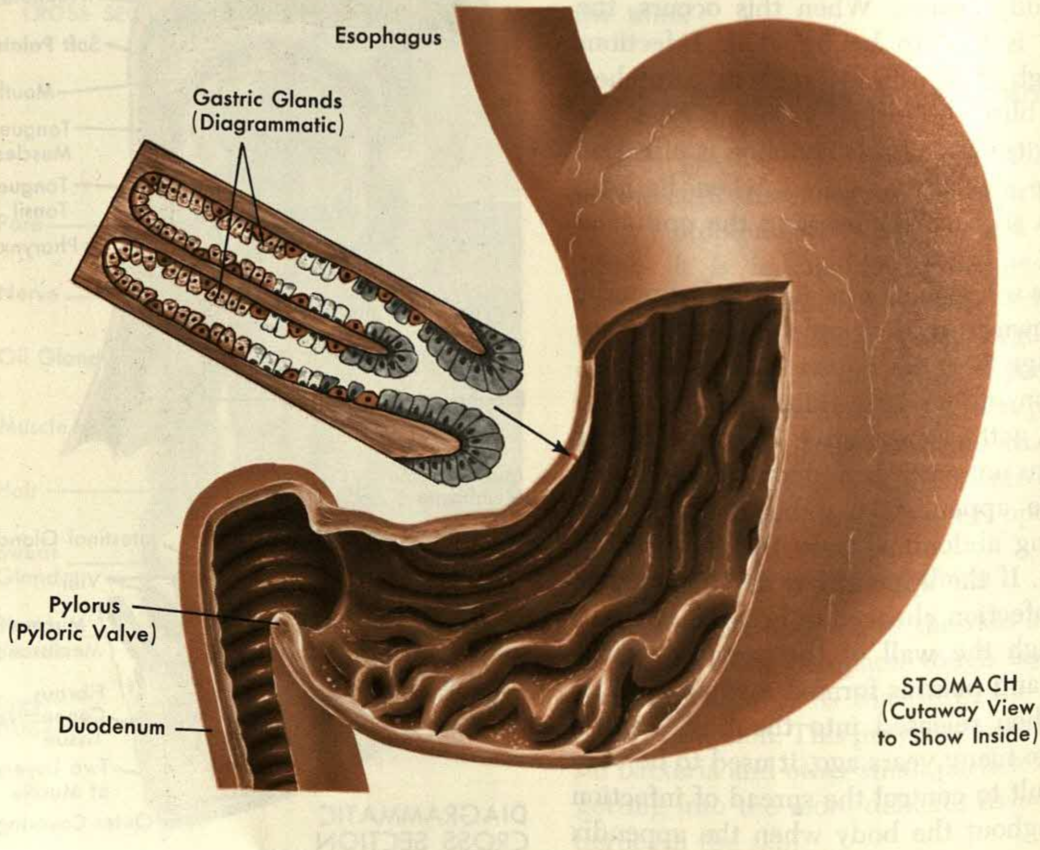
The seriousness of a ruptured appendix is known to most people. As you can see on page 504, the appendix is a small extension of the large intestine. It is also lined with a protective membrane. For reasons not entirely understood, the lining of the appendix may become infected, causing abdominal pain that persists for hours. If the appendix is not removed or the infection checked, a break may occur through the wall of the appendix. Bacteria and poisons formed in the appendix are then released into the body cavity. Not so many years ago, it used to be very difficult to control the spread of infection throughout the body when the appendix


MUCOUS MEMBRANE OF NOSE
(Mag. 40 X)


DIAGRAMMATIC CROSS SECTION OF HUMAN INTESTINE



The normal appendix, above, left, is only a small extension of the large intestine. When infected, as at right, above, appendix becomes red and swollen. Cutaway view of stomach, below, shows the gastric glands which supply hydrochloric acid needed for digestion.



Esophagus
Gastric Glands (Diagrammatic)
Pylorus (Pyloric Valve)
Duodenum
STOMACH (Cutaway View to Show Inside)

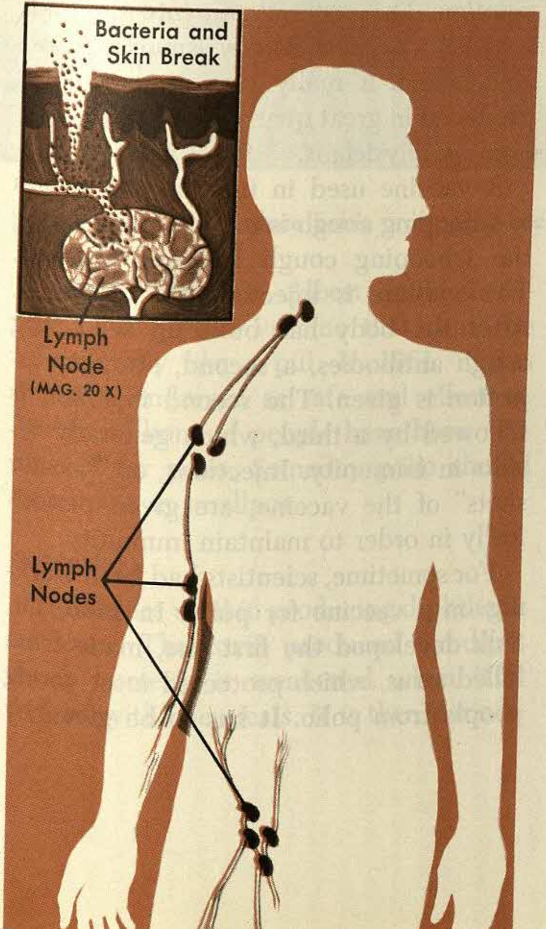
wall broke. Today, antibiotics make this a less serious problem.

Body Fluids

Tear glands, located in the eye socket above the eyeball, give off tears that pick up bacteria and other particles that may get into the eye. The tears, draining from the eye through tubes that empty into the nose, thus wash away the particles.

Have you ever noticed how you have to blow your nose after you have been laughing or crying? Tears are draining through your nose. At what other times do tears form?

You will recall that tiny glands in the lining of the stomach give off juices containing hydrochloric acid during digestion. Although the amount of hydrochloric acid present in the stomach at one time is very small, it is enough to destroy many bacteria that enter the stomach with the food you eat.



INTERNAL BODY DEFENSES

Whenever an infection occurs in the body, internal protectors take up the task of defending it. You have probably cut or scratched a finger and observed that the skin around the wound became red, or inflamed, and that later pus formed within the wound.

Inflammation indicated that a greater supply of blood was being furnished the infected area. Materials from the blood form a tough wall around the infection, which helps to keep it from spreading to surrounding tissues.

Leucocytes

The blood, in addition to red cells, also contains many millions of white blood cells, or leucocytes, which are extremely small and have an irregular shape. They can squeeze through very tiny openings in the walls of blood vessels and move into an infected area of the body. Here they actually consume the harmful organisms. So many millions of them collect that you can see a white spot which is called *pus.*

Fighter Cells

Other special cells located in blood and lymph vessels also destroy harmful organisms much as the leucocytes, or white blood corpuscles, do. As blood passes through the blood vessels, some of the germs that may have entered the blood are removed. When lymph passes through lymph glands, such as those located in the neck or in the armpit, germs in the lymph are also removed.

Antibodies

When germs get into body tissues, cells of the body may produce chemical substances known as ***antibodies.*** One kind of antibody, ***antitoxin,*** makes harmless the poisons, or toxins, produced by invading organisms. Other antibodies destroy certain organisms, or make it easier for white blood cells to consume them.

Whenever a person has recovered from diseases such as measles or chicken pox, enough antibodies have been produced to protect him from the harmful effects of the disease in the future. He is then said to be ***immune*** to the disease. His protection, or ***immunity,*** may last for only a short time, as in the case of the common cold, or it may last for life, as is often the case when one has recovered from a case of measles.

IMMUNIZATION

By helping the body to produce antibodies, it is possible to ***immunize*** it to some diseases. One way to do this is to inject into the body the dead, or weakened, disease-producing germs. These germs cause the body to produce antibodies without the person becoming ill with the disease.

More than a hundred years ago, an English physician, Edward Jenner, discovered that persons who had recovered from cowpox, a mild disease, were immune to smallpox, which is very serious. He then wondered if it would be possible to immunize persons to smallpox by injecting them with pus from the sores of cows suffering with cowpox. Being a scientist, Jenner knew that the only way he could answer this question was actually to try it. He found that persons so treated became immune to smallpox.

Vaccines

The virus which causes cowpox is a weak relative of the smallpox virus. When it is introduced into the skin of a human being, the inflammation which forms on the arm is the mild disease, cowpox. But the antibodies which are developed will protect the person from smallpox. Putting weakened, or dead, organisms into the body to develop immunity is called ***vaccination.*** The material put into the body is called a ***vaccine.*** Today "smallpox" vaccine, which is really cowpox vaccine, is produced in great quantities and is widely used by physicians.

A vaccine used in immunizing babies to whooping cough is produced by killing the whooping cough bacteria by heat. This vaccine is injected into the body. After the body has built up whooping cough antibodies, a second, stronger injection is given. The second injection is followed by a third, which generally results in immunity. Injections, or "booster shots" of the vaccine, are given periodically in order to maintain immunity.

For sometime, scientists had been working on a vaccine for polio. In 1955, Dr. Salk developed the first one, made from killed virus, which protected most young people from polio. It has to be given by

Photos by Chas. Pfizer & Co., Inc.

Technicians, left, produce Sabin oral polio vaccine, which is distributed for community protection.

injection. Then Dr. Albert Sabin developed a live polio vaccine that could be taken orally like a pill. In 1961, it was officially endorsed as safe and effective. Today millions of people have been vaccinated for polio. Someday polio should be as rare as smallpox.

Antitoxins

Horses are used in producing diphtheria antitoxin. The toxin produced by diphtheria bacteria is weakened when it is treated with chemicals. It is then periodically injected into horses which have a high resistance to the disease. The amount of toxin is increased with each injection. Before long, the horse's blood contains a large amount of diphtheria antitoxin.

Blood is then taken from the horse, and the liquid portion of it containing the antitoxin is separated from the rest. This liquid portion is called ***serum.*** After the serum has been carefully tested for strength of antitoxin, it can be injected into persons suffering from diphtheria to help their bodies fight the disease. The effect of a serum which a person receives from another person, or an animal, does not last long. It is given only to a person suffering from a disease.

For a person to become permanently immune to diphtheria, his own body must produce antitoxins. All children should receive injections beginning in infancy so that they can build their own immunity to diphtheria. These injections do not contain dead, or weakened, germs, such as the vaccines used for whooping cough and polio. They contain only the chemical ***toxin*** (poison) which has been dissolved out of the diphtheria bacteria. But the toxin is first treated so that it will not be harmful. This harmless chemical is called a ***toxoid***, which means, "somewhat similar to a toxin." It can still stimulate the body to form antibodies. Three injections of diphtheria are given in infancy, and then a booster shot is given every two years.

There is also a toxoid to develop immunity to tetanus, or lockjaw. Nowadays babies are usually given a combined injection which contains diphtheria and tetanus toxoid and whooping cough vaccine. Then a booster shot is given every few years to take care of any decrease in immunity.

The diseases to which people can be immunized effectively, together with the methods of immunizing them, are listed in the table below. But among those to which people cannot be immunized are mumps and colds.

Success of Immunization

Immunization has greatly decreased the number of people who suffer from certain diseases. Smallpox used to be one of the most dreaded of diseases. Today, a case of smallpox is rare in those states which require vaccination.

Human Diseases Largely Controlled by Immunization

Disease	*Type of Agent Causing It*	*Method of Immunizing*
Diphtheria	Bacterium	Toxoid
Tetanus	Bacterium	Toxoid
Typhoid	Bacterium	Vaccine
Whooping Cough	Bacterium	Vaccine
Rocky Mountain Spotted Fever	Rickettsia [1]	Vaccine
Epidemic Typhus	Rickettsia	Vaccine
Influenza	Virus	Vaccine
Smallpox	Virus	Vaccine
Rabies	Virus	Vaccine
Yellow Fever	Virus	Vaccine

[1] Organisms having characteristics similar to both bacteria and viruses.

Inoculations

Inoculation, or the injection of substances into the body, may be used to help the body counteract poisons from the bites of snakes and spiders. Rattlesnake poison, or ***venom,*** is obtained from rattlesnakes and injected into another animal, whose body produces antitoxin to counteract the poison. Blood serum from the animal, containing the antitoxin, is used to inoculate persons who have been bitten by rattlesnakes.

Many hayfever victims have been relieved by inoculations. As you will recall, some people suffer from hay fever because their bodies are highly sensitive to certain plant pollens. Tests can be given to these patients to determine the plant pollens to which they are sensitive. A series of injections containing the offending pollens is begun and continued for several months. By the time the pollen season arrives, it is hoped that the sufferer will have lost all, or some of, his excessive sensitivity. Hayfever victims differ in the extent to which they can be helped by inoculations.

Chemotherapy

For many years, scientists tried to find chemicals which could be used to control harmful organisms in the body and yet not harm the body cells. Their search has been successful for a number of diseases. A number of chemicals have been discovered that can be used in this manner.

Quinine and ***atabrine*** (AT-uh-brin) are used to check the development of the organisms causing malaria.

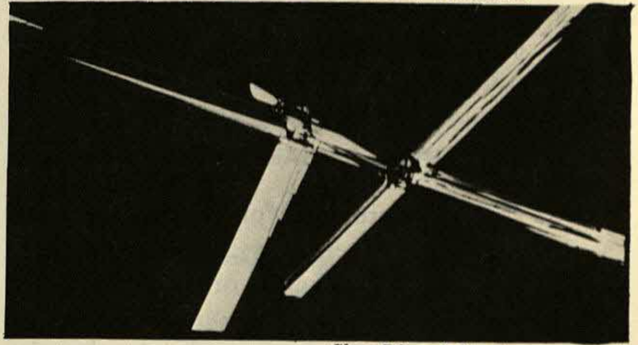
Several different kinds of sulfa drugs are used in the treatment of diseases

American Museum of Natural History

Rattlesnake, above, is being milked for venom.

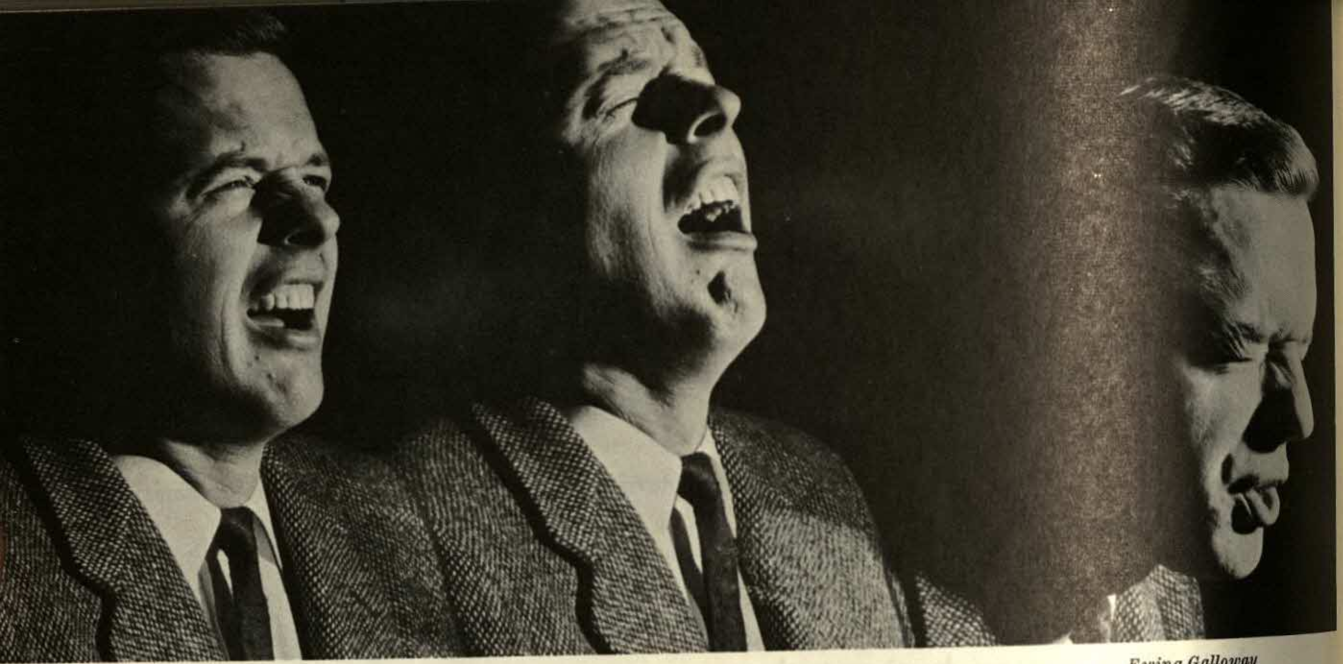
Many are sensitive to pollen of the ragweed.

United States Department of Agriculture



Chas. Pfizer & Co., Inc.

Chemotherapy has developed such antibiotics as magnamycin, which has a rod-like structure.



Ewing Galloway

A sneeze like the one above often sends thousands of disease germs into the air. Anyone who breathes in this air can then become infected by these germs.

caused by certain bacteria and viruses. Penicillin, ***streptomycin, aureomycin,*** and ***chloromycetin,*** chemical substances obtained from molds and called antibiotics, have been used with great success in treating many different kinds of diseases which are known to be caused by bacteria and viruses.

The use of chemicals, such as sulfa drugs and antibiotics, in treating diseases is called ***chemotherapy.***

CONTROL OF HARMFUL ORGANISMS

Disease-producing organisms are spread in many different ways. Whenever a person with a cold coughs or sneezes without properly covering his mouth, a fine spray of moisture is discharged into the air. Each droplet of the moisture may carry some cold-producing organisms, which persons in the vicinity may inhale. The germs of measles, chicken pox, colds, sore throats, and many other common contagious diseases are spread on moisture in the breath, even without sneezing or coughing. This is why sick people should stay at home.

Disease-producing organisms can also get into the body by being carried to the mouth on unclean hands. Foods handled by ill persons, or produced under unclean conditions, may become contaminated with germs.

Pork worms can be transferred to the intestine when improperly cooked infected meat is eaten. Malaria germs, found only in the blood of a person suffering from malaria, can be transferred to another person's blood by a particular type of mosquito that has bitten the person infected with the disease.

Pasteurization of Milk

Milk is heated to destroy disease-producing microörganisms that might be in it. It may be heated to a temperature of 142°F to 145°F and held there for thirty minutes, or it may be heated to 160°F for a much shorter period of time. This process is called ***pasteurization*** and is required by law in most places before milk is sold. Pasteurized milk may become unsafe again if it is not protected from contamination after it is pasteurized.

Proper Sewage Disposal

Because many harmful organisms are eliminated from the body in human wastes, it is vital that provision be made for safe disposal of sewage.

Control of Small Animals

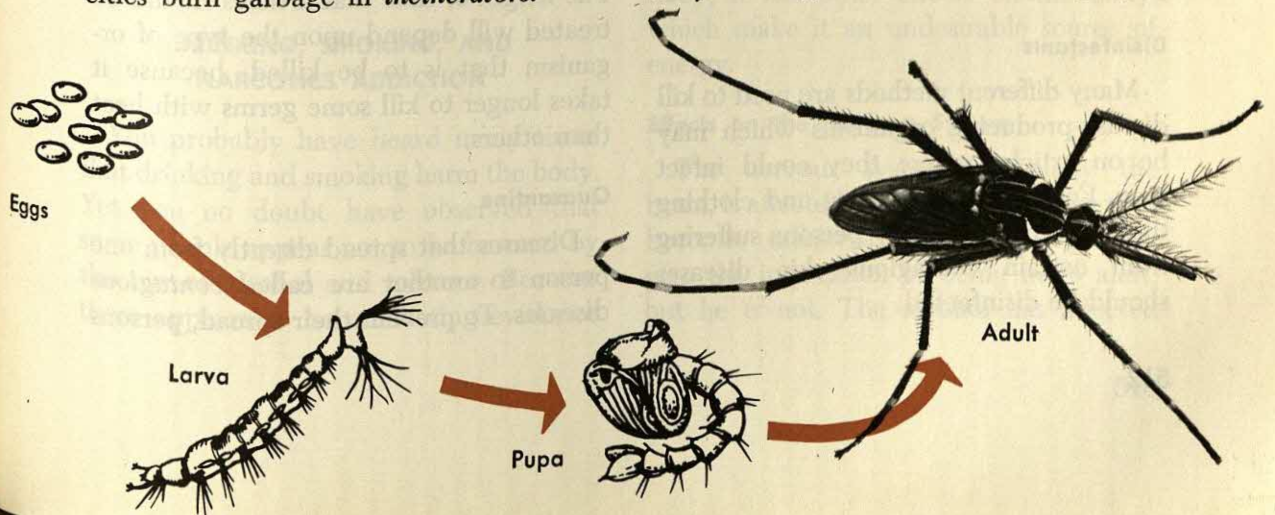
Flies can carry disease germs to humans. The places where flies and other insects produce their young are called ***breeding places.*** Garbage and other filth are common breeding places. If flies are to be controlled, therefore, garbage must be collected and properly treated, streets kept clean, and houses screened to keep out flies. Many different methods of garbage disposal have been tried, but the most effective method is to burn it. Many cities burn garbage in ***incinerators.***

Mosquitoes can also be controlled by destroying their breeding places. Mosquitoes lay their eggs in water. The eggs hatch into worm-like organisms called ***larvae*** (LAHR-vee), which then develop into adult mosquitoes. Swamps, puddles, or stagnant vessels of water may become a breeding place for them. Whenever practical, therefore, swamps should be drained, and tin cans, barrels, and other containers removed, or kept covered, so that they will not collect water.

Whenever it is not practical to drain swamps or puddles of water, they should be sprayed with oil. The oil forms a thin film over the water and kills the mosquito larvae by making it impossible for them to get air.

Rats must be destroyed in order to control the disease called ***bubonic plague,*** which occurs in some parts of Asia, for they can become infected with the germ causing this disease. Fleas may bite infected rats and then transfer the germs to humans. Proper disposal of garbage and ratproofing of buildings where rats might obtain food are the most effective ways of controlling them.

The germ causing ***typhus fever,*** which is rare in America, is carried from one person to another by body lice, which live on dirty clothing and on the bodies of people



Sometimes a health department quarantines house in which a person with a contagious disease lives. This is to prevent visitors from coming in contact with sick person and spreading disease.

Coburn from Monkmeyer

who are not able to keep themselves clean. During World War II, it was not always possible for soldiers at the front to keep their bodies and clothing clean. In order to destroy body lice, soldiers dusted their bodies and clothing regularly with a powder containing the chemical DDT.

A number of poisons are used to kill insects that carry disease germs. Today it is possible to obtain small bombs which produce a fine mist of a liquid that is poisonous to insects.

Disinfectants

Many different methods are used to kill disease-producing organisms which may be on articles where they could infect man. For instance, bedding and clothing that have been used by persons suffering from certain contagious skin diseases should be disinfected.

Anything that is used to kill microörganisms is called a ***disinfectant.*** A number of different chemicals are used as disinfectants, as well as the ultraviolet radiations discussed in Unit 4, page 206. Heating objects to high temperatures is one of the best ways to kill harmful organisms. This method is used regularly in hospitals to sterilize instruments.

Boiling and steaming are effective methods of using heat as a disinfectant. The length of time that articles should be treated will depend upon the type of organism that is to be killed, because it takes longer to kill some germs with heat than others.

Quarantine

Diseases that spread directly from one person to another are called ***contagious*** diseases. To prevent their spread, persons who are ill with them should be kept away from anyone who is not immune. The practice of isolating such persons is called ***isolation*** or ***quarantine.***

Water Purification

The water supply must be carefully guarded if it is pure to start with. If not, the water must be purified with a chemical, chlorine.

Public Health Departments

The prevention of contagious diseases is one of the important functions of city, county, and state public health departments. Workers in these departments keep records of all cases of serious contagious diseases. By locating and controlling sources of contagious diseases, they can prevent epidemics.

Representatives of public health departments also inspect food sources frequently. In some cities, food handlers are examined periodically to determine whether or not they are carrying disease germs. Dairies are inspected regularly to make sure that the milk is clean. Drinking water, as well as water in swimming pools and at bathing beaches, is tested periodically to make sure that it is safe for human use.

DRINKING, SMOKING, AND NARCOTICS ADDICTION

You probably have heard many times that drinking and smoking harm the body. Yet you no doubt have observed that some people appear not to be harmed by the use of alcohol and tobacco. Because there appears to be conflicting evidence regarding the effects of alcohol and tobacco, it is important to determine the facts. However, there is no question about the harmful effects of narcotics, as you shall see in your study of this problem.

ALCOHOLIC BEVERAGES

The alcohol in alcoholic beverages is ***ethyl*** alcohol, produced by the action of microörganisms upon sugar. Wines are manufactured by allowing yeast to act upon the sugar in fruit juices and to change some of it to alcohol. Beer and whiskey are manufactured by changing the starch in certain grains, such as rye and barley, to sugar, and then allowing microörganisms to produce alcohol from the sugar.

Wines contain about 14 percent alcohol by volume, beer about 6 percent, and the stronger liquors 40 to 50 percent.

Alcohol as Food

There has been much discussion as to whether or not alcohol can be considered a food. Because alcohol can be used neither to build body tissue nor to regulate essential bodily processes, it lacks two essential characteristics of food. Although it can be used to produce energy in the body, it has other effects on the body, which make it an undesirable source of energy.

Effects on the Nervous System

The nervous system, especially the brain, is affected by alcohol. A person who becomes talkative when drinking may give the impression of being more alert, but he is not. The alcohol has affected

THE BRAIN AND ALCOHOL

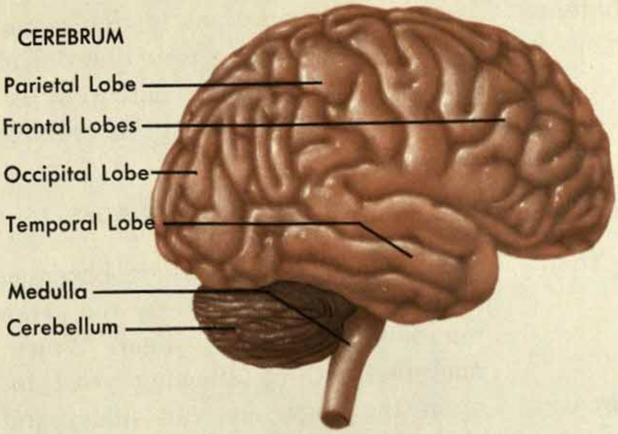


Diagram of the brain shows the different areas which are affected in varying degrees when you drink alcoholic beverages.

parts of his brain which exercise judgment and a sense of what is proper. As a result, the person talks with little consideration for what he is saying. Serious and important matters about which he should be concerned do not bother him so much when he is under the influence of alcohol. Because of this, some people begin using alcohol as a means of forgetting their worries. Others may use alcohol at parties or other social gatherings because they believe it helps them to become more sociable and thus enjoy such events.

A number of tests have been performed to determine the effects of alcohol upon the speed with which a person reacts. Results of these tests have proved that a person who has been drinking reacts more slowly and less accurately. For these reasons, it is dangerous for anyone who has been drinking to drive an automobile, or perform other activities involving the safety of human life.

Alcoholism

Some people can drink small amounts of alcoholic beverages occasionally without feeling that they have to drink regularly. Others, once they have developed the habit of drinking, find it difficult to stop. These people are called habitual drinkers. Some of them use alcoholic beverages regularly, but in moderate amounts, whereas others find it necessary to drink increasingly large amounts. There is one group of drinkers who, after taking one drink, are unable to stop. This type of drinker is generally referred to as an ***alcoholic***. An alcoholic may consume so much alcohol that death results.

Alcoholics cannot live normally. They often lose their positions and become dependent upon relatives or social institutions for their care. It has been estimated that there are three-quarters of a million alcoholics in the United States.

Effects on Health

Insurance companies have studied how drinking affects the number of years a person may live. They have found that excessive, or heavy, drinking shortens a person's life. Heavy drinking definitely seems to interfere with mental activity, reduce resistance to infection, and lower the general health of the individual.

TOBACCO

Smoke from tobacco contains a number of substances, including ***nicotine,*** which may have harmful effects on the body.

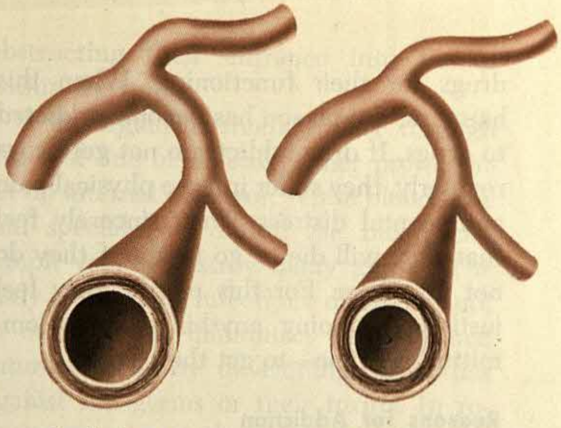
Smoking frequently causes irritation of the nose and throat and chronic cough. There is strong evidence that the smoking of cigarettes is the principal cause of lung cancer. Smoking is also believed to favor ***arteriosclerotic*** (ahr-teer-ee-oh-skler-OT-ik) heart disease in late life. In some cases, smoking causes a loss in appetite and a shortness in breath. The experience of many athletic coaches indicates that a person can be a better athlete if he does not smoke.

The Smoking Habit

Most people who have become regular smokers find it very difficult to give up the habit. Many have tried to give up smoking since the discovery of the connection between lung cancer and smoking. But a great majority have failed. To go without smoking makes them feel uncomfortable and nervous. They often say, "I only wish I had never started." Young people who start smoking do so because they want to feel grown up. Science has shown that this is a foolish way to gain that feeling.

NARCOTICS

Narcotics include opium, morphine, codeine (KOH-dee-in), heroin, and a number of other drugs which have a numbing effect on the body. Some of these drugs are used by doctors for short periods of time to relieve the pain of their patients.

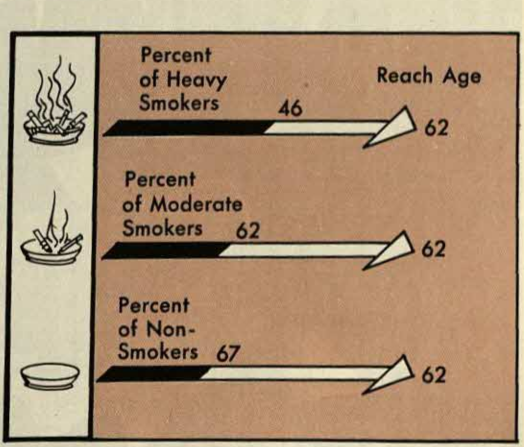


Narcotics Addiction

If people take narcotics over a period of time, they usually form a habit and cannot get along without them. This is called ***addiction.***

The use of some of these drugs may actually cause changes in body tissues, which require the continued use of the

The chart below shows the relation between life span and smoking habits.



drugs for their functioning. When this happens, the person has become ***addicted*** to drugs. If drug addicts do not get drugs regularly, they suffer intense physical pain and mental distress. They sincerely feel that they will die or go insane if they do not get them. For this reason, they feel justified in doing anything—even committing a crime—to get their drugs.

Reasons for Addiction

Some addicts started to use drugs to relieve physical pain, or to escape facing their problems. Many younger addicts got their start because of curiosity, or a desire to make an impression upon someone. Most of them followed the same pattern of behavior. First they tried alcohol, then marijuana (mair-uh-WAH-nuh), and, finally, heroin.

Prevention of Addiction

Before 1914, there were no laws to control the use of narcotic drugs. Today, however, there are laws that limit the amount that can be produced, or brought

Wide World photo

Customs official searches airline luggage to prevent smuggling of narcotics into the United States.

into this country. Narcotic drugs can be legally used only for medicinal purposes, and their use is under very close supervision. However, the unscrupulous narcotics peddler attempts to persuade young people to try smuggled drugs because he can make a living off them as soon as they have become slaves to the habit.

Certain drugs called ***barbiturates*** (bar-BICH-uh-ratz), commonly used in sleeping pills, have been found to be habit forming for some individuals. They can be obtained only with a prescription issued by a physician.

SUMMARY

The body must be supplied with the proper nutrients if it is to work efficiently. Some nutrients are used to supply energy and build up the body, while others regulate its activities, including its growth rate. The amount of different nutrients that an individual should obtain from his foods depends upon his size, age, sex, and the kind of activities in which he engages.

Health, gracefulness of movement, and personal appearance are improved by proper exercise of the muscles of the body. Adequate rest and sleep are essential if body and mind are to function well.

Living organisms which enter the body may cause disease by producing toxins or destroying tissues.

Other causes of illness may be a lack of essential nutrients in the diet, or a failure of certain tissues and organs of the body to function properly.

External coverings and fluids help protect the body from harmful organisms by obstructing their entrance into tissues within the body.

If an organism should break through this first line of defense, other protectors set up internal defenses. White blood cells and special cells lining the blood and lymph vessels destroy many germs. The body overcomes infectious diseases, and, in many cases, immunizes itself against future attacks by developing antibodies against the germs or their toxins. In recent years, chemicals and antibiotic drugs, such as penicillin made from molds, have been discovered. They greatly aid the body in overcoming certain diseases caused by bacteria and viruses.

Harmful organisms can enter the body through air, food, water, or contact with contaminated objects. To prevent harmful organisms from entering the body, they may be killed before they enter the body; material in which they may develop can be destroyed; or small animals such as insects, which carry the organisms, can be controlled.

Smoking is known to produce cancer and heart disease. The habit is very difficult to break but easy to avoid. The decision for life is usually made in the teen years.

Alcoholic beverages impair judgment and skill and frequently help to cause serious automobile accidents. A proportion of those who drink alcoholic beverages become alcoholics and destroy their careers and the happiness of their families.

Because of its disastrous effects upon human beings, everyone should be alert to any possible situations which might lead to drug addiction.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The substances in food that are used by the body are called (a) diet (b) allergies (c) nutrients (d) food misconceptions.

2. Because they are growing, boys have a greater need than men for (a) fats (b) vitamins (c) proteins (d) water.

3. Very small disease-producers which cannot be grown outside of living cells are called (a) viruses (b) protozoa (c) bacteria (d) antibodies.

4. Any organism that lives upon another organism is called (a) toxin (b) parasite (c) microörganism (d) fungus.

5. Many bacteria are prevented from entering the body by (a) the skin (b) white corpuscles (c) antibodies (d) blood.

6. Some germs which may be in the blood are removed by special cells as the blood passes through the (a) heart (b) lungs (c) lymph vessels (d) intestines.

7. Putting weakened, or dead, organisms into the body to develop immunity is called (a) inoculation (b) vaccination (c) chemotherapy (d) inflammation.

8. The use of chemicals in treating diseases is known as (a) immunization (b) inoculation (c) vaccination (d) chemotherapy.

9. An effective method of controlling mosquitoes is to (a) collect their eggs (b) use nets to keep them out of houses (c) vaccinate people (d) destroy their breeding places.

10. A person who has been drinking a great deal of alcohol is (a) more alert (b) reacts more rapidly and accurately (c) reacts more slowly and less accurately (d) considers carefully what he says.

B. Conducting Further Investigations

1. Will saliva change starch to sugar?

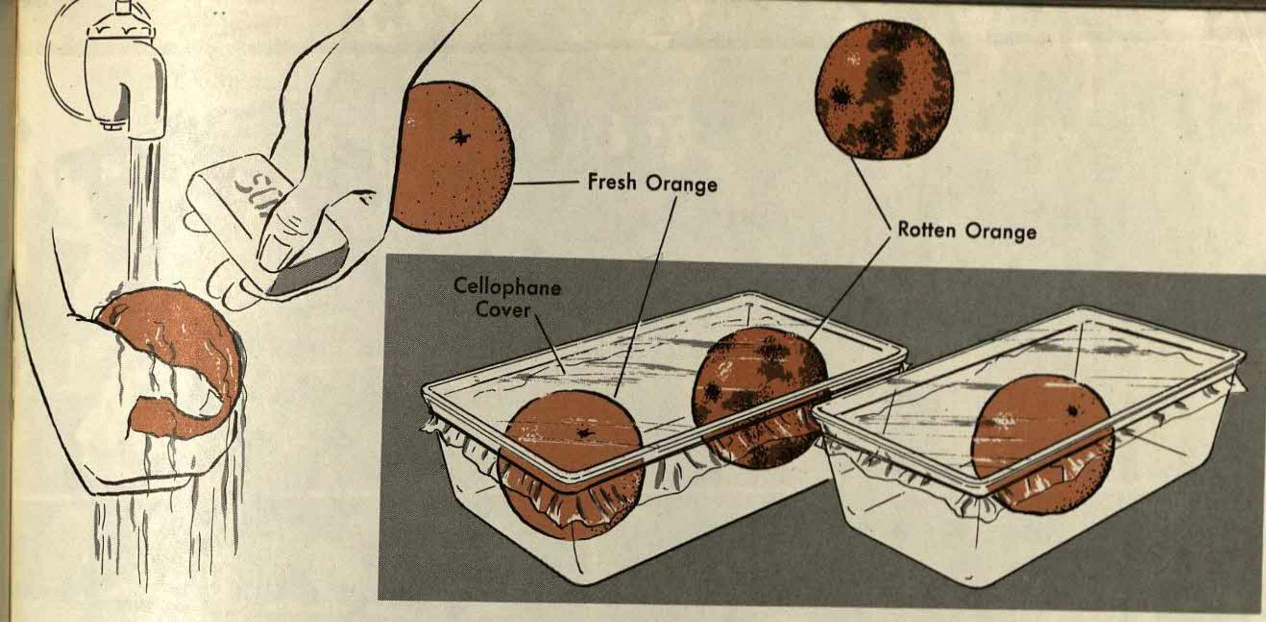
Test pieces of cracker for starch and sugar by using the tests described on page 484. Test some class member's saliva for starch and sugar. Have him chew a cracker well in order to mix it thoroughly with the saliva in his mouth. Have him note any change in flavor as he chews. Place some of the chewed cracker into each of two test tubes. Test the contents of one for starch and the other for sugar. Repeat the experiment with other pupils.

Why were unchewed crackers tested for starch and sugar? Why was the saliva tested before the cracker was chewed?

2. It was pointed out in this unit that the germs causing some diseases are readily transmitted from person to person. It is not possible for you to experiment with people to see if this is true. However, you can experiment to see if the fungi infecting an orange will be transmitted to another orange.

Obtain a rotten orange that is rather completely covered with molds and other fungi. Carefully examine this fungi.

Wash two fresh oranges well with warm water and soap. Then rinse each orange in boiling water.



Cover the bottoms of two deep pans with five layers of wet paper towels. Put a fresh orange into each pan. Place your rotten orange into one of the pans as far from the fresh orange as possible. Cover both pans with cellophane so that the towels stay moist.

Set the pans in a warm place and observe the oranges daily. Which of the fresh oranges will become infected first? How long will it take for each of them to become infected? How can you tell whether the fungi from the rotten orange infected the fresh one? How many times would you have to do this experiment to be sure of the results you got the first time? In what ways does this experiment follow Koch's rules as listed on page 499?

3. Do flies carry bacteria?

Plan an experiment to find out if several live flies are carrying bacteria on their bodies. Use the materials and procedures described on page 409 to carry out your experiment.

4. How do three different disinfectants compare in their ability to retard the growth of microörganisms?

You will need four bottles, a cup of dried beans, solutions of equal concentrations of three different disinfectants of your own choice, sterile absorbent cotton, and water.

Soak the cup of beans in water for several hours. Put the same amount of beans in each of the four bottles. Cover seeds in bottle No. 1 with boiled water which has been cooled. Cover the beans in each of the other bottles with a solution of one of the disinfectants. Stopper all bottles with sterile absorbent cotton and put the bottles in a warm place. After several days, remove the plug from each bottle and smell the contents.

From which bottles is there an odor? What caused it? On the basis of this test, how would you judge the effectiveness of the three disinfectants in controlling microörganisms?

Sybil Shelton from Monkmeyer

PROBLEM 4: WHAT IS BEHAVIOR?

Unit 9 began with the generalization that living things differ from non-living things in that they respond to their environment. Not only are they capable of responding, but they seem to be engaged in doing so most of the time.

Observe some of the animals in your environment and you will see a constant stream of activity. The ant, the fly, the bee, the squirrel, and, above all, the bird, are continually on the move. Each is responding to stimuli in a manner determined by its structure. A gorilla cannot respond to a danger signal by flying through the air to safety, but he can run or climb, or he can use his great strength to overcome dangers.

Human beings, too, are active creatures. Watch your fellow students in study hall, and note how much they move even when they are supposedly still. You will see nervous movements of the hands and fingers, crossing and uncrossing of legs, shifting in seats, facial movements, contortions of the lips.

AUTOMATIC ADJUSTMENTS

What causes this constant stream of behavior? As you learned in Problem 2, some behaviors are involuntary. They are automatic adjustments that the body is equipped to make. The concept of ***homeostasis*** (hoh-mee-oh-STAY-sis) is often employed to explain these behaviors. By homeostasis is meant the tendency of the body to keep internal conditions stable. Because stimuli are constantly being received which upset this stability, there is a constant stream of activity to restore stability.

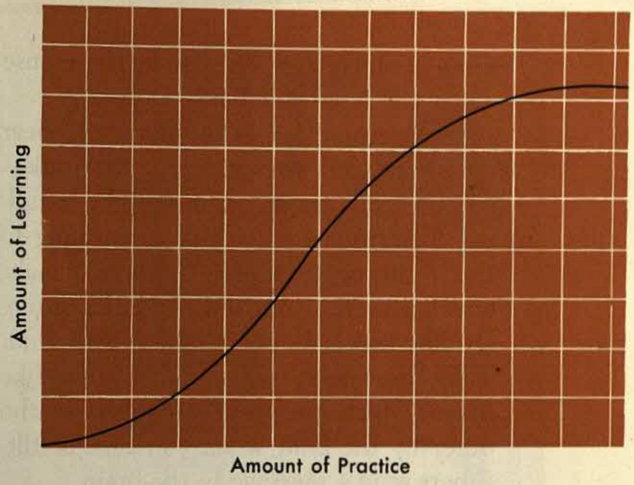
On an excessively hot and humid day, it is more difficult for the body to get rid of the internal heat which is being created constantly by every muscular, glandular, and circulatory activity, in order to maintain temperature homeostasis at a normal level. Perspiration increases so that the skin will be cooled by evaporation. The heart rate increases to pump more blood to the skin. The blood vessels in the skin dilate, giving it a pinker appearance. The person automatically becomes less active. The increased loss of water through perspiration upsets the homeostasis of the body's fluid balance, and messages go to the brain, which the person recognizes as thirst.

If the air temperature suddenly drops because of a thunderstorm or air conditioning, the homeostasis is upset in the opposite direction. Blood vessels in the skin contract and the skin becomes pale. Goose pimples appear which, in our remote ancestors, made their fur stand on end for greater warmth. Shivering may occur. This is an involuntary muscular activity to create more heat. If these automatic processes are not sufficient to restore homeostasis, the person may become conscious of his body's discomfort and deliberately take other means to warm himself.

But not all behaviors can be explained in terms of automatic adjustments. Behaviors such as playing a Beethoven sonata, catching a baseball, or learning to play chess are under conscious control. You learn such behaviors, and even learn to want to learn them.

MAN'S EQUIPMENT FOR LEARNING

Man comes into the world well-equipped to learn. He has many sensory receptors that enable him to receive stimulation from the outside world. In the process of evolution, he has developed specialized equipment which makes it possible for him to respond to different kind of stimuli.


LEARNING PROCESS

Man's Many Senses

Man can see, hear, taste, and smell. These senses, together with a sense of touch, are the most familiar to you. However, the term "sense of touch" does not accurately describe all of this kind of receptor with which the body is equipped.

There are some receptors in the skin which enable you to sense pressure or contact, while others, also in the skin, enable you to sense pain or temperature change. Receptors in muscles, tendons, and joints permit you to sense movement, and receptors within the inner ear signal changes in equilibrium.

It is the ability to sense pressure that makes it possible for you to feel your way in the dark and for the blind to read Braillo with their finger tips. Receptors in the muscles help you to learn touch typing. Every key on the keyboard feels the same upon contact, but you learn to sense when you have struck a right key.

Semicircular canals in your skull, near your ears, tell you—even in the dark—whether you are standing upright or falling forward; whether you are turning to the right or to the left. These canals, which give you your sense of equilibrium, are like tiny hollow tires filled with fluid. They are lined with minute, hair-like fibers, which are pushed one way or the other by the fluid when you turn or tilt. Fibers send a message to the brain.

If you should steadily rotate a glass of water in which you saw dust floating, you would notice that the water at first did not move, but that the glass moved around it. Gradually the water would pick up speed. When you stopped rotating the glass, water would continue to circulate in it for a few seconds.

If, in the same way, you should shut your eyes and someone should spin you around in a revolving chair, the fluid in your semicircular canals at first would not move. The canals would move past the fluid. This is what tells you that you are rotating, and in which direction. If the person should keep spinning you around for a while, the fluid would pick up speed. When you stopped rotating, the fluid would continue to move in the canal for a few seconds. Because the fibers were being pushed in the direction opposite from which they were first pushed, you would now have the sensation of rotating in the opposite direction. See page 124.

Still other sensory receptors in the skin are stimulated by pain and temperature change. What other sensory receptors can you name?

Senses for Learning

You rely upon four of the senses—vision, hearing, pressure, and the muscular sense—to provide you with the stimulation that makes learning possible. You make less frequent use in learning new behaviors from messages received through your senses of taste and smell—unless, perhaps, you are employed as a tea-taster or a perfume tester.

This is also true with the sensory receptors to pain and temperature. These serve, in the one case, to alert the body to danger, and, in the other, to make possible homeostatic adjustments. They less frequently serve to convey messages that directly influence learning.

Sensory Receptors of Lower Animals

Lower animals are not so plentifully endowed with specialized sensory receptors as is man, but all have some degree of sensitivity to light. The amoeba, being a one-celled animal, has, of course, no specialized sensory cell. However, the protoplasm of which its one and only cell is composed is light sensitive. Stimulate it with a strong light and it seems to flow slowly away. See page 441.

As you move up the evolutionary tree, you find animals such as the starfish, still without an organ of sight, but with a light-sensitive pigment at the tips of its rays, or arms.

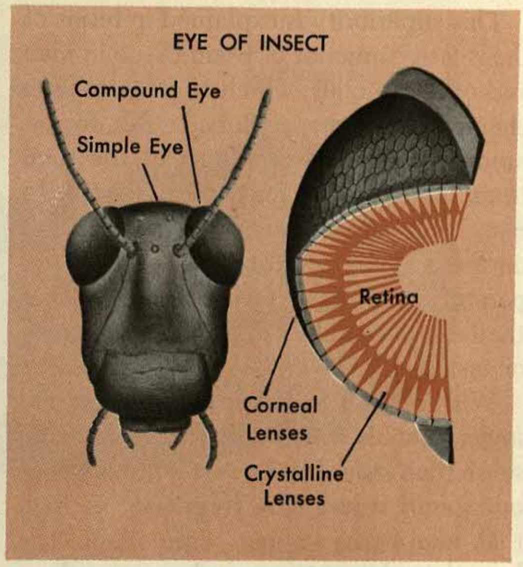
Still higher animals, such as insects, have image-forming eyes. Each eye is made up of hundreds of individual, light-gathering parts. These eyes are called ***compound eyes.*** Eyes of animals are oval-shaped organs that can not only form images, but that can also bring images into sharp focus if the distance is not too great.

The ability to detect darkness from light, and to detect direction of movement, which is possessed by some animals, is very important to them for survival.

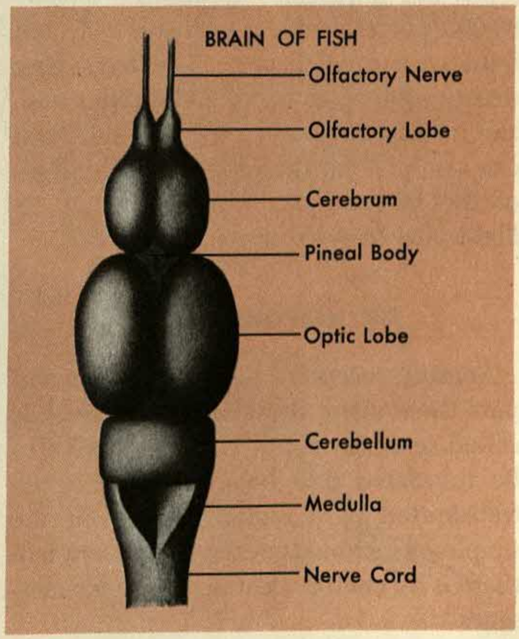
The ability of the fly or the cockroach to sense a shadow falling upon it alerts the insect to danger and makes it difficult to kill. Bear down upon a roach with a swatter, and by the time the swatter falls, the roach will have scurried out of the shadow to safety. It is aided in its escape attempts by its ability to make lightning calculations as to the direction from which the swatter is coming.

Some animals can use light from the sun to get their bearings as they move about. Birds and bees appear to have this ability. So do some other insects. Turn a ladybug around as it marches toward the sunlight, and you will soon see it circle about until light from the sun again shines into its eyes from the same direction it did before you disturbed it. In what way may the ability to take directions from the sun have had survival value?

While man is plentifully endowed with specialized sensory receptors, not all of his senses can outperform those of animals. This is particularly true of the chemical sensory receptors of taste and smell. Bees can detect odors with their antennae a relatively greater distance away than can man. The dog can outsmell man, and so, too, can the catfish.



The compound eye of an insect is shown above. It is made up of many individual parts. Below is the brain of a fish. Note the large areas given over to taste, sight, and smell.



This superiority is explained in terms of the relative amount of brain tissue in man and other animals, which is given over to chemical sensory receptors. In fish, for example, more than one-third of the total brain is specialized for taste and smell. In man, only a very small portion of the cortex is given over to these senses. Apparently man has survived by means other than a superior ability on his part to smell or taste.

With respect to hearing, too, there are lower animals which possess a more acute sense than man. It is known that bats send out sound waves of a frequency so high that man's ears cannot sense them. The bats then detect the sound waves, when, like echoes, they are reflected back from objects they strike against.

Not so well known is the fact that certain moths also have a remarkable sense of hearing. Their mortal enemy, the bat, sends out ultrasonic vibrations (40,000–80,000 per second), which are reflected from very small insects. The bat's very sensitive ears pick up the reflected sound, and it swoops upon its prey. But the moth can also pick up the ultrasonic vibrations of the bat and can quickly change its flight plan to avoid becoming a meal.

THE NERVOUS SYSTEM

Sensory receptors pick up stimuli and pass them along the fibers of nerve cells called ***sensory nerves.*** For the impulse to be translated into behavior, it must be transmitted to a motor neuron. In the simplest beginnings of the nervous system there is no central clearing house for messages.

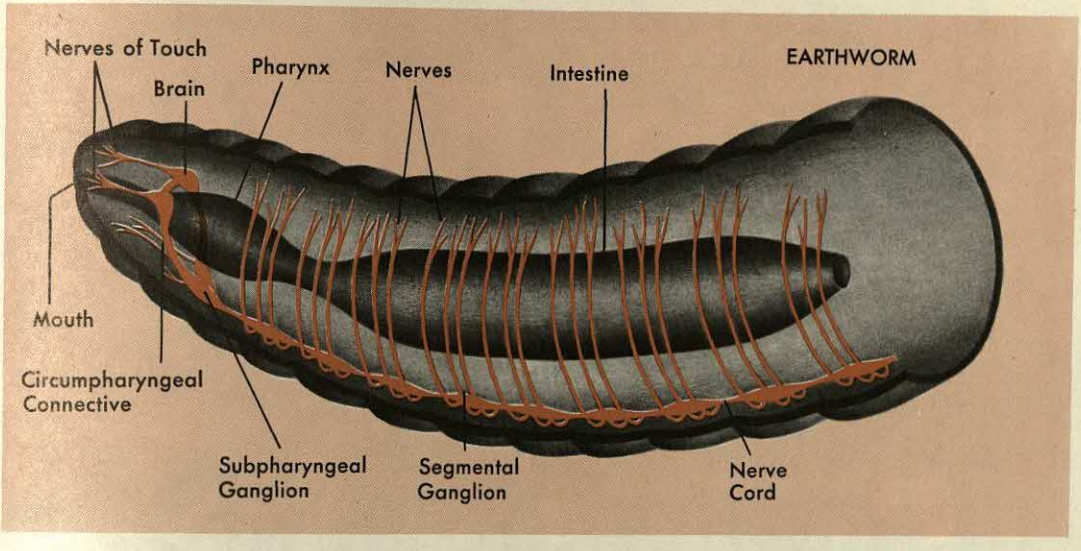
The ***hydra,*** for example, has no brain at all. Instead, it has a network of nerve-cell fibers directly connecting the various parts of the organisms with one another. The flatworm has a more advanced type of nervous system, with clusters of nerve cells that act as go-betweens for stimulus and response. The earthworm represents a still higher type, in that the switching is done in chains of ***ganglia*** (GANG-lee-uh), which are swellings of gray matter strung along a nerve cord. They are located at each segment in the worm, and control that segment. The nerve cord connecting the ganglia leads to a larger ganglion in the head, which acts like a brain and helps the earthworm function as a whole.

MAN'S BRAIN

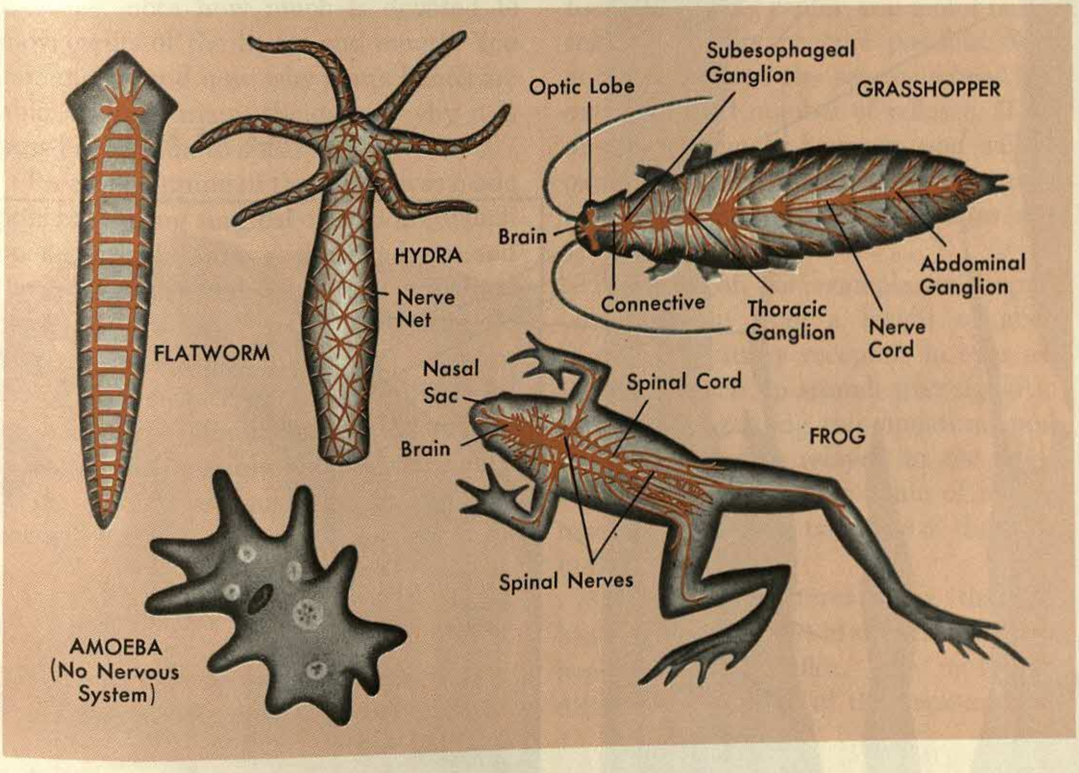
In man, a spinal cord extends upward into the skull to become the brain stem. The brain stem in turn branches out into the cerebellum at the back of the brain and two cerebral hemispheres at the top of the brain. These hemispheres are covered with gray matter called the ***cortex.*** It is composed of nerve cells which connect with nerve fibers leading to lower centers of the brain and to the spinal cord. The complex setup of man's brain makes possible a far greater choice of behavior in response to sensory stimuli than the lower animals can command.

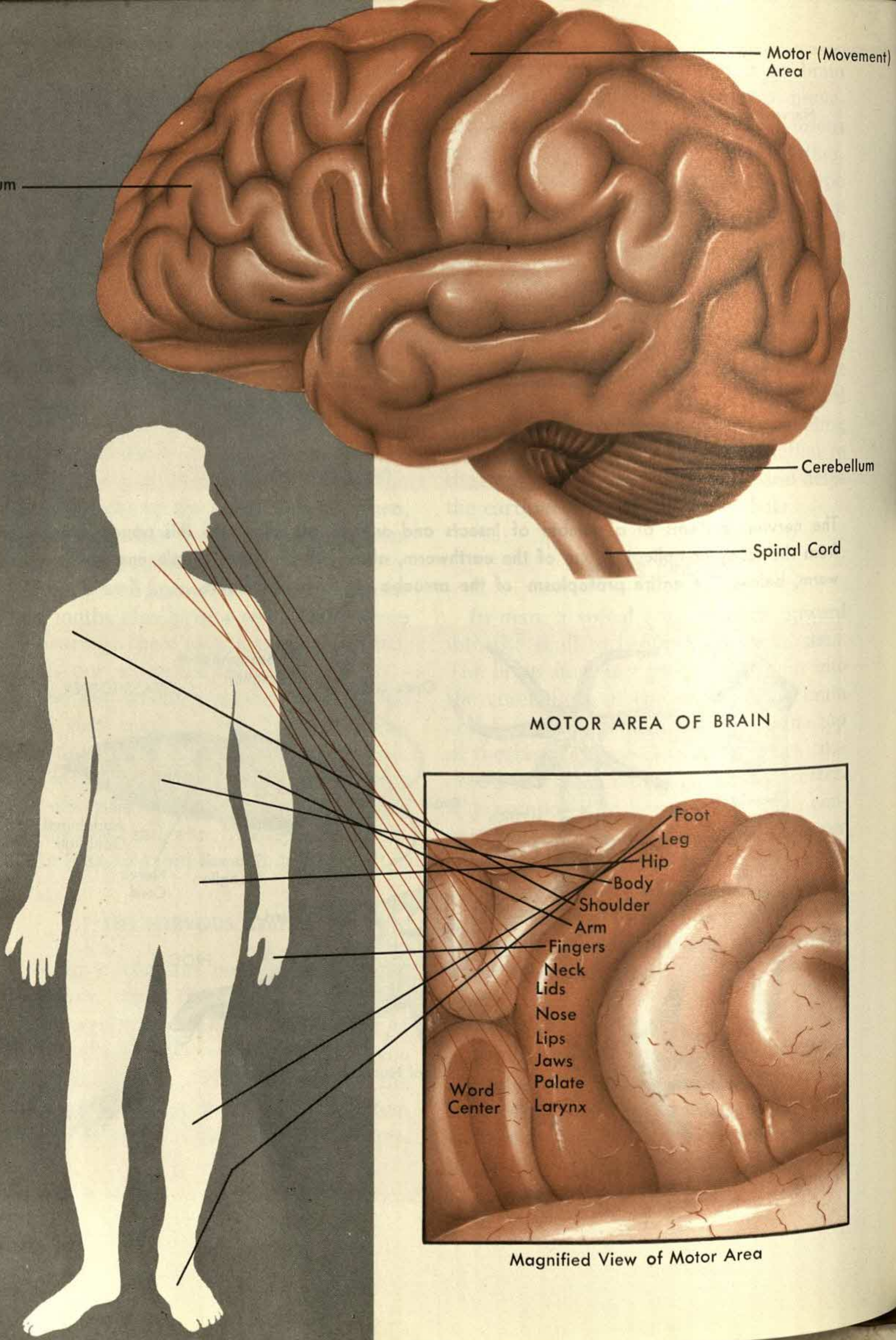
Mapping the Cortex

You will note from the map of the cortex on page 526 that there are separate areas, each of which is especially designed to carry on one or more functions. In the separate diagram of the motor area, for



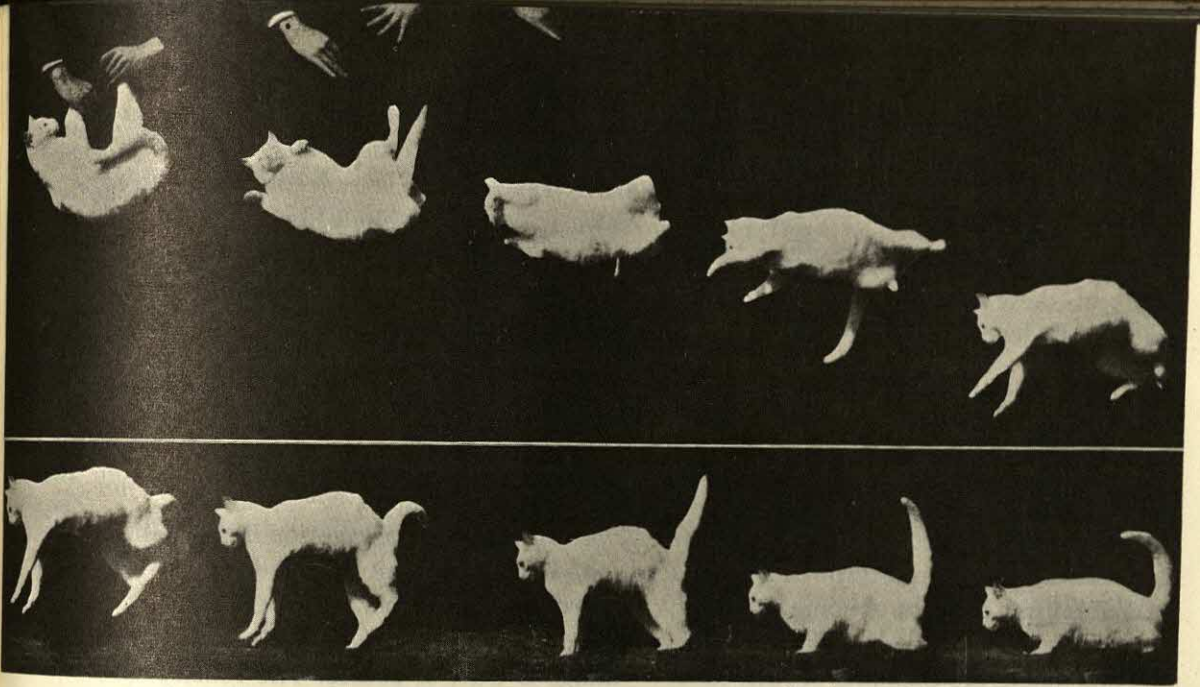
The nervous systems of a number of insects and animals are shown on this page. They range from the fairly complicated one of the earthworm, above, to the fairly simple one of the round worm, below. The entire protoplasm of the amoeba reacts to stimulants.





MOTOR AREA OF BRAIN

Magnified View of Motor Area



Renaissance of the Greek Ideal by Diana Watts

Reflex behavior of falling cat, from time it is dropped until it lands on feet, is illustrated above.

instance, note how much is devoted to movements of the hands and mouth. You can understand now why man's hands are able to do so many things and why it is possible for him to speak.

Precise mapping of the cortex was made possible during surgical operations, which opened up the human skull and exposed the cerebrum while the patient remained conscious. An electrode carrying a gentle current was applied to different areas on the cortical surface to stimulate them. By applying such stimulation at the proper place, it was possible to raise the finger of the patient although the patient did not will it.

REFLEX BEHAVIORS

As you move up the evolutionary tree to animals which possess sensory receptors, a switching center, and motor nerves, reflex behaviors become possible. Some animals, such as the sea anemone, have only a limited number of reflexes. If you observe mammals, however, you will see patterns of reflexes operating in a marvellously coördinated way. See pages 474–475.

When a cat, for example, is dropped with feet up from a height of about three feet, sensory receptors in eyes and inner ears pick up stimuli that signal information regarding this unnatural position. The news is relayed to the spinal cord and immediately a chain of reflexes is set into motion to take care of the situation.

Slow-motion pictures show that the head rights itself first in what is called the head-positioning reflex. This movement distorts the position of the neck and sets off a neck-positioning reflex. This, in turn, is followed by a righting of the thorax, and, finally, the hind section. The cat spirals around in a series of quick movements which begin with the head. As a result of these reflexes, the cat usually lands on its feet.

The Reflex Center

For a long time, a rather simple model was used to explain reflexes. The model showed a reflex center in the spinal cord where incoming messages from sensory organs were transferred through synapses to a structure capable of some response. Such a structure is called an ***effector.*** Muscles and glands are examples of such effectors.

There is some feeling among scientists today that at least some behaviors that were formerly explained by this model can better be explained by a ***mechanism*** called a ***feedback loop.*** Instead of a simple switching over of messages to effectors, there is a mechanism in the reflex center that does some testing of messages in terms of information already available in nerve cells. Information is then fed back into the system and input is modified.

You can understand how this feedback loop works if you think about how the idea is used in modern electronics. One example is in the control of the amount of illumination an area receives. In classrooms and offices being built today, lights brighten automatically as natural light fades, and lights dim as natural light brightens. Information about how much illumination is available is continually being fed back into the system, and the amount of current is then adjusted.

It may be that some kind of feedback loop explains the reflex behaviors of animals. Take the cockroach and its ability to escape a swat. Stimuli signaling change from light to dark and sudden movements are transformed into electrical energy, and messages are flashed to the reflex center. There, with computer-like speed, the center sizes up the input against information already on hand, makes lightning-like calculations, and acts accordingly to change input.

The foregoing description may sound as if the roach were engaged in what is called intelligent behavior, and as if he could exercise free will. Neither of these things is true, of course. The roach's behavior is completely involuntary. But much of its total behavior is probably under the control of feedback loops that coördinate input and output. Unlocking the secret of feedback mechanisms and built-in computers in the nervous system of animals is a challenging task.

INSTINCTIVE BEHAVIORS

In higher animals, more complex, but still unlearned, behaviors are found that involve many reflexes appearing one right after another. Some behavioral scientists like to refer to these more complex patterns as ***instinctive behaviors.*** The term refers to a series of actions characteristic of a species, which are carried out in a very definite sequence. The behavior of your pet dog in turning round and round in its basket before settling down to sleep is an example of instinctive behavior. So is the behavior of animals when courting, nesting, and caring for their young.

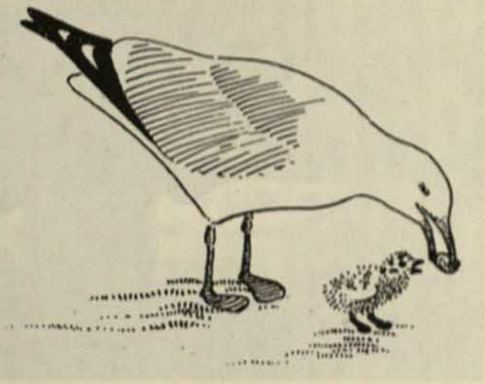
One writer has given a detailed account of some instinctive behaviors in a certain type of tropical fish that is velvet black with deep turquoise blue spots which change color. First the male and female engage in nest-building activities. After the eggs are laid, both fan a stream of water toward the eggs in the nest.

When the babies hatch out and are in the swimming stage, their parents lead them out of the nest each day to search for food. As daylight fades, the mother returns to the nest and signals her young to return by jerking her fins up and down. At this signal, which makes the jeweled spots shine like a flashing mirror, the young descend to the nest. The father, meanwhile, searches for stragglers, inhales each one into his big mouth, swims homeward, and ejects each one into bed.

A Releasing Mechanism

How can such instinctive behaviors be explained? Are animals born with such a pattern already fixed in the nervous system? Does it emerge regardless of what happens to the animal after birth? This question has interested behavioral scientists for some time.

The answer seems to be that there is no fixed pattern in the nervous system at birth, which will emerge according to a built-in timetable. Rather, the animal is born with a framework that is roughed in instead of being finished in all of its details. Furthermore, whether or not this rough framework of cells is activated, and what it looks like in its finished form, depends upon a stimulus to trigger it. The stimulus, of course, is received through a sensory receptor. Not any stimulus will do. Only a specific kind can signal the nervous system and activate the rough framework of cells.



From Tinbergen

Herring gull chick pecks at mother's bill tip.

The releasing stimulus is different for different behaviors. Scientists have discovered what it is for some behaviors. They have, for instance, experimented with the pecking response of chicks. All normal chicks peck, but if they are blindfolded at birth, the pecking response may not develop. Is the sight of the mother hen or other chickens pecking what sets off the pecking response? Apparently this is not necessary.

The stimulus that sets off the pecking response in the herring gull chick is the red spot at the top of the mother's bill. Because the mother more often than not has a choice morsel of food in its bill, the chick is stimulated to continue pecking for food after its initial peck. If chicks are raised in an incubator and do not see an adult bird after hatching, the pecking response can be set off by showing the chick a red spot on a piece of cardboard.

U. S. Fish and Wildlife Service

Goslings, above, exhibit typical "following" response as they paddle around pond behind mother.

Imprinting

Experimenters have worked with ***following responses*** of some animals to learn more about how such behavior can be released. Animals such as ducklings, goslings, and lambs are among those which follow the mother one right after the other. But if animals with a following response do not see their mother after birth, they will follow whatever moving object does release this response. Everyone knows how faithful Mary's little lamb was to her. And one university professor was always followed down the street by the family's pet goose, which preferred the professor to its own mother!

The process by which instinctive behavior becomes fixed is called ***imprinting.*** In the case of the goose, its following response became imprinted to the professor.

From research it is known that the imprinting process is not reversible. A lamb that had been imprinted with respect to a human being was put out to pasture with other lambs. It showed no interest in following its mother, as the other lambs did, but waited for the man to appear and trotted after him. The gosling whose following response was imprinted to the professor could not unlearn this behavior and start all over again.

Critical Period for Stimulation

Research also shows that there is a very limited time during which imprinting can occur. What that time is depends upon the response involved. Early infancy is an especially ***critical period.*** By a critical period is meant that period when an organism is particularly sensitive to a certain kind of stimulation.

For some responses, imprinting can occur only during the first forty-eight hours after birth. If the stimulation is not received during that limited period, then the behavior will never appear. The chicks that were blindfolded at birth and remained blindfolded during the critical period for the appearance of pecking never did learn to peck.

The concept of a critical period for development has long been applied to development before birth, too. It appears that there are critical periods for the development of each organ. A disturbance in the environment of a developing animal or human being can injure that organ. What organ will be defective depends upon which part of the organism is developing at the time of the disturbance.

There is a timetable for the development of different organs. An organ is most vulnerable to injury at the time of its fastest growth. It is this brief period of time which is called the critical period. The same disturbance after the critical period has passed will not affect organs that are already formed.

If a pregnant mouse, for example, is deprived of oxygen during the period when the bodies of its babies are developing, they develop such defects as a harelip, or a badly formed skull. If it is deprived of oxygen while the ear is being formed, the offspring may be deaf, but its vision will not be affected.

Certain diseases such as German measles have been known to cause a disturbance in the environment of a developing human being. The first three months of pregnancy make up the period in human development when the major organs of the body are being formed. It is known that German measles can result in deafness, blindness, or mental deficiency in the human infant if the disease is contracted by the mother at this time. The particular defect depends on whether the organs of sight, hearing, or the association areas in the cortex are being laid down at the time of disturbance. Hence it is during this period in particular that care must be taken to protect the body from diseases that might disturb the environment of the developing organism.

INTELLIGENT BEHAVIOR

The concept of a critical period for certain kinds of development has raised a great many questions, most of which are still unanswered. Perhaps one of the most interesting is the question of whether or not there is a critical period for the development of certain kinds of behavior other than instinctive. Are certain periods critical for the development of intelligent behavior? Is there a critical period when sensory stimulation is necessary?

Need for Sensory Stimulation

Suppose an animal or human being is deprived of stimulation during the so-

Chimpanzee had only limited opportunities to move. Would restrictions affect behavior?

American Journal of Psychology

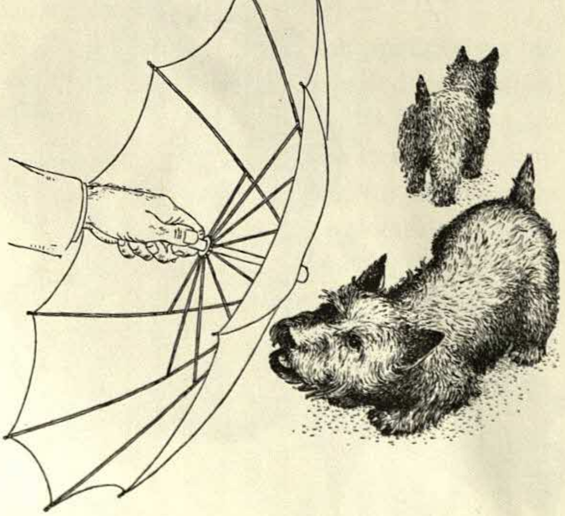
called critical period. What are the effects upon intelligent behavior? How do animals develop if they have a minimum of stimulation?

There have been a number of experiments which show that animals need sensory stimulation if they are to develop into good problem-solvers later in life. The experiments also show that the critical period in this development occurs in early infancy.

In one experiment, Scottish terriers from the same litter were divided into two groups. Animals in one group were sent to families who raised them as household pets. In such an environment, the dogs received a great deal of stimulation from a tremendous variety of smells, sounds, and other sensory stimuli. The dogs in the other group, by contrast, were reared in individual, soundproof cages, completely enclosed, and so constructed that feeding and cleaning could be done by the keeper without his being seen by the dogs. You can see that, under such conditions, sensory stimulation was kept to a minimum.

Dog whose behavior had been restricted was always frightened by opening of umbrella. Dog which had received normal stimulations accepted umbrella and was not frightened by it.

Scientific American



How did the dogs fare later on? After months of living under these two sets of conditions, both groups of animals were brought together and tested. In one test, an umbrella was slowly opened to see how the dog would respond to a strange event. The pet dogs barked in normal fashion, but the others waited several months before showing this response. Other tests were designed to see how well each animal could adjust its behavior to changing conditions.

Each dog, for example, was trained to get food in a certain place. Then the food dish was put in a different spot while the dog looked on. The pet dogs realized immediately that the food dish was in a different spot. Apparently having a chance to experience a variety of stimuli gave them practice in sorting out the important ones from the unimportant. But the dogs raised under conditions of minimum stimulation kept going back to the original corner for food.

Do human beings need sensory stimulation to develop normally? Experiments such as the one with the dogs cannot, of course, be carried on with human beings to obtain the answer to this question. In the first place, it would be unethical for a behavioral scientist to carry out an experiment that might have harmful effects of a permanent nature. Some years ago, however, one investigator did discover in an orphanage infants who were being raised under conditions of minimum stimulation. This kind of orphanage no longer exists, principally because of what scientists have discovered about the need for stimulation. The babies were given excellent physical care, but they were kept in cribs curtained with sheets from floor to ceiling, and they had no toys to play with. In other words, there was little to stimulate their senses. The investigators discovered that these babies were slow to learn concepts, and, in general, were poorer thinkers than institution babies reared under conditions which provided greater stimulation.

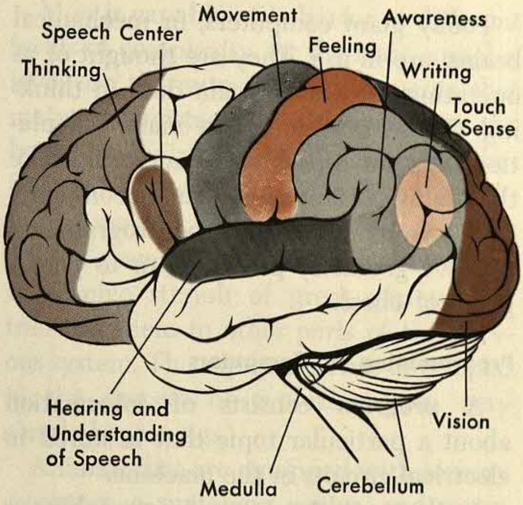
As the infant plays with his toys, he picks up ideas of what things are like—hard or soft, warm or cold, light or heavy. He learns what tastes good and what does not, how things differ in shape, which things fit together, and how things compare in size. All of this elementary knowledge provides the infant with a foundation for learning more complicated things later on.

Nature of Intelligent Behavior

When you bounce a ball on the floor to demonstrate how light is reflected from both smooth and rough surfaces, your behavior is not the simple reflex, nor the instinctive behaviors, so far discussed. Such behavior is called ***intelligent behavior.*** It is more flexible than the behaviors already discussed, and is directly influenced by learning. Animals are capable of intelligent behavior, too, although man is quite justified in his claim to superiority.

It is generally believed that intelligent thinking takes place in those parts of the cerebral cortex known as the association areas, which make up the greatest part of man's brain. They are represented in diagram above by tinted areas. Here are stored memories, concepts, and learnings.

ASSOCIATION AREAS OF BRAIN



When an electrode was applied to a spot in one of the association areas during the type of operation previously described, the patient reported the memory of something that had happened years before. The experience was more real than remembered. It was almost like reliving the event, although the patient was conscious and knew where he was.

But when these few words have been said about what goes on in the brain in the course of intelligent thinking, you have said practically all that man knows about this organ. He knows that there can be no thought without an accompanying physical activity in the brain. There is no such thing as a mind apart from the brain. But man has learned little about the brain. Behavior is studied and inferences drawn about what is going on in the brain, but scientists do not know whether these inferences are correct.

MECHANICAL BRAINS

Today giant computers, or mechanical brains, are in use. They are thought of as operating the way a brain does in thinking. These machines can make calculations and solve problems that would take the brains of many men years to complete. Such machines can even be programmed to solve geometry problems, or to play a game of chess.

Programming of Computers

A *program* consists of information about a particular topic that is stored in electrical circuits in the machine.

In the geometry-computing machine, a number of basic formulas, together with rules for using them, are stored in the machine, which is also given some strategies to try. For example, built into the machine is the information that if parallel lines and equal angles are involved in the problem, then there is a certain theorem, or law, that can be applied to solve the problem. The machine will try one strategy after another until it finds one that works satisfactorily.

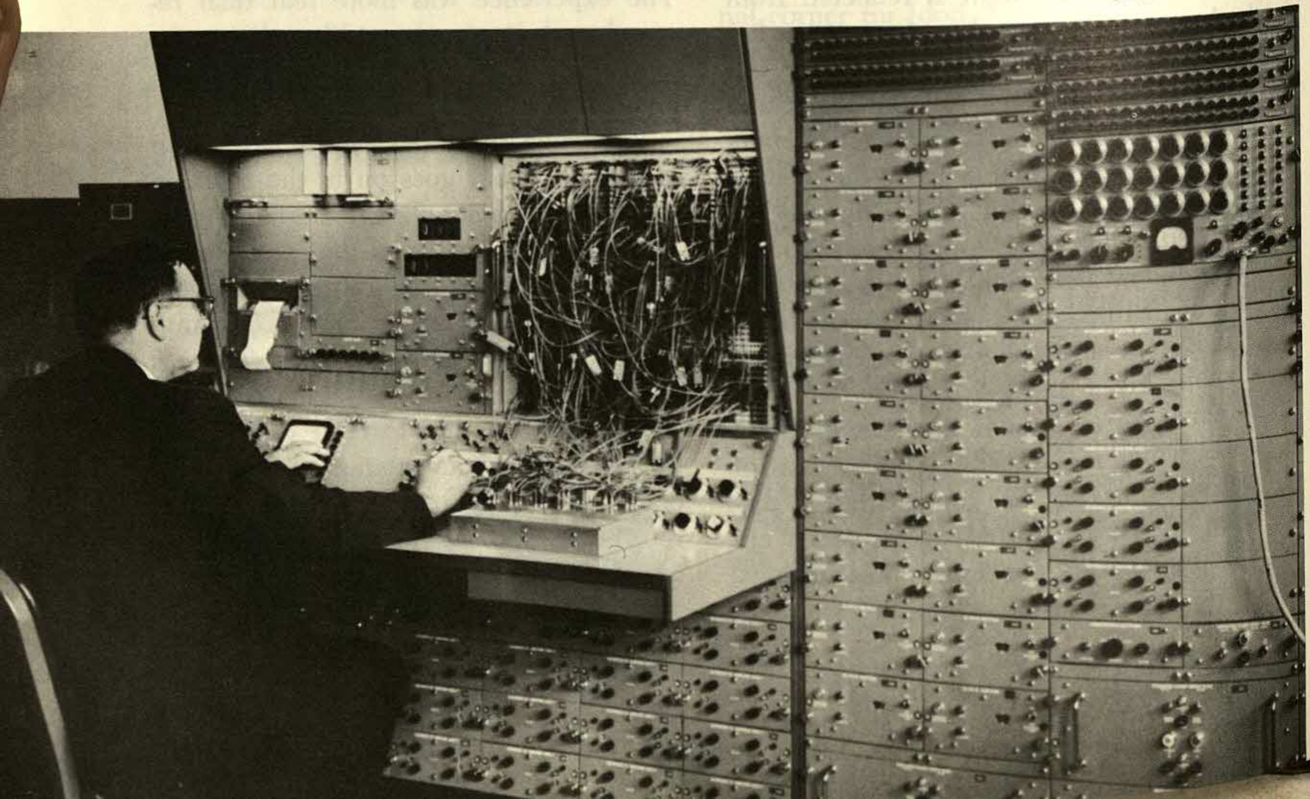
To program a machine, man must think through all the steps that he takes to solve a problem, and all the rules and strategies that he knows. Once the information is stored in circuits in the machine, the computer can "remember" all the possible strategies better than can most people. Because of its wonderful memory, a machine can be built that can play a better game of chess, or solve geometry problems faster than can the person who programmed the machine.

Learning Problem-Solving

Although the geometry machine can solve problems, it cannot learn to solve

Giant computer, below, is one of mechanical brains used by the steel industry to process data.

U. S. Steel Corp.



them. It will solve a problem the same way each time until it is given different instructions. When man solves a problem, he usually finds out something about problem-solving in the process. In other words, he learns to solve problems and improves his methods of learning in the process. Building into the computer the ability to learn problem-solving is a task on which many scientists are now working.

Some people like to argue about whether or not machines will eventually take the place of man in today's civilization. This is a rather pointless argument. What machines can do is to take over the job of solving many problems that now take up man's time and free him for the creative work of which he is capable.

One of these creative tasks is for man to find out more about himself in general and the brain in particular. Most of the brain is an enormously complex mystery. One scientist has suggested that you can get some idea of the brain's complexity if you think of it as comparable to the whole telephone system of the United States. This system's tremendously involved network of electrical circuits makes possible a choice of connections so vast as to be difficult to comprehend. In the brain, as electrical potential moves along nerve fibers, the choice of pathways is enormous. One choice of pathways connects certain nerve cells, and one train of thought results. To understand what is happening, and how it happens, remains man's greatest challenge. And as this mystery is solved, perhaps many of the problems of human behavior can also be solved satisfactorily.

SUMMARY

Man is capable of behavior at different levels of complexity. At the least complex level are the automatic adjustments that maintain constant conditions within the body. At the most complex level are behaviors that result from intelligent thinking by man.

Man's sensory equipment enables him to receive stimuli of great variety and transmit them to other parts of the nervous system. This equipment has developed in the process of evolution from very simple beginnings.

Animals that are equipped with sensory receptors, a switching center, and motor nerves are capable of reflex behaviors. It is now believed that a feedback loop better explains how an impulse gets translated into behavior than does a simple switching mechanism.

Instinctive behaviors are complex unlearned behaviors which appear in a definite sequence and are unique to a particular species. Such behaviors require for their first appearance some sort of releasing stimulus.

The term critical period is applied to the relatively short span of time when development of the organism can be permanently affected by the environment.

Early sensory stimulation appears to be necessary for proper development of problem-solving ability. It is not known exactly what goes on in the brain in the course of such development.

Giant computers have been built which simulate human thinking. As yet, machines have not yet been built that can learn to think.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The concept of homeostasis would not include (a) perspiring (b) the taking of salt tablets in hot weather (c) increase in blood pressure under conditions of fear (d) restless behaviors after sitting for some time.

2. The chemical senses are (a) vision and hearing (b) vision and equilibrium (c) taste and hearing (d) taste and smell.

3. All animals have (a) sensory receptors of several kinds (b) at least one type of sensory receptor (c) some sensitivity to light (d) a sense of vision.

4. All animals have (a) a nervous system of some kind (b) a capacity to respond to their environment, even without a nervous system (c) a switching center where sensory stimuli are transmitted to motor nerves (d) ganglia, or swellings of nerve cells along a nerve cord.

5. A relatively large proportion of the motor cortex in the human brain is devoted to the work of the (a) trunk (b) hand (c) eyeball (d) hip.

6. It is believed that a satisfactory model to explain reflex behaviors is (a) a feedback mechanism (b) the reflex arc (c) a simple switching center (d) a synapse.

7. Instinctive behaviors, such as the nesting of birds, (a) appear without fail at the appropriate time (b) result from the imitation of other birds (c) are released by some kind of stimulus (d) are learned from other birds.

8. Following responses in animals can become imprinted (a) during a relatively short period of time after birth (b) only while the animal is being cared for by its mother (c) any time after birth (d) when it is an adult.

9. Considerable sensory stimulation in infancy is necessary (a) for the development of instinctive behaviors (b) for homeostatic adjustments (c) to prevent the appearance of defective organs (d) for later intellectual development.

10. The most important contribution of giant computers is their (a) ability to out-think man in problem solving (b) saving of man's time for those jobs which only he can do (c) planning of a better civilization for man (d) performance of calculations which man cannot do.

B. Making Special Reports

1. Cold-blooded animals are more inclined than warm-blooded ones to seek an environment where few homeostatic adjustments to temperature are necessary.

Here is a project which you can carry out to show this tendency. You will need a long, narrow box such as a shoebox. Collect a number of insects of one species —ants or ladybird beetles—and put them into the box. Do they prefer any special spot in the box?

Now devise some method of cooling the bottom of the box at one end and of heating it at the other. How do the insects respond? Can you try other experimental conditions?

Make a special report to the class on your procedures and results. Attention to minute details in your observations will make your report interesting.

2. One of the most famous of living scientists engaged in a study of animal behavior is Karl Lorenz. His delightful book, *King Solomon's Ring,* is a good source of information for special reports on instinctive behaviors. Here are some suggestions for reports you can make after reading it.

a. The social and family life of birds
b. The language of animals
c. Instinctive behaviors of fighting fish

3. Organize a committee to prepare reports on the evolutionary development of the nervous system. Select animals which illustrate progression from simple to highly complex nervous systems. Have each committee member be responsible for investigating the nervous system of one animal and for making a report to the class. Slides, chalk board drawings, or special charts can be prepared to illustrate each report. Examples of interesting animals to study are: the hydra, earthworm, common starfish, crayfish, fish, frog, turtle, bird, whale, monkey.

C. Preparing Demonstrations

You have probably noticed that if you twirl yourself around in a circle, you do not feel dizzy while you are going around, but only after you stop. The concept of inertia helps to explain this lag. By inertia is meant the tendency of a body to remain at rest if at rest, or to keep moving in the same direction if in motion, unless some force acts on it from the outside.

You will recall that receptors for your sense of equilibrium are located in canals in the inner ear. These canals contain a liquid. When you twirl, you apply a force to the skeletal framework of your body. The canals twirl, but the liquid in the canals has a tendency to remain at rest.

Prepare a demonstration that will illustrate what happens in the inner ear. Half fill a bucket with water and then give the bucket a sharp spin. Describe what happens to the water. Try a sharp twist to the right and follow it immediately with a sharp twist to the left. What happens to the water? Attach fine strips of paper to the sides of the bucket at the waterline. These can represent the sensory hairs in the canals. How do the strips move relative to the amount of water?

Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review some of the important ideas in this unit.

1. How is your body like an amoeba?
2. What five examples can you give of how the structure of different cells of your body is related to their particular functions?
3. In what four ways did your body develop from a single fertilized egg?
4. Why was it necessary for the various tissues of your body to grow in step with each other?
5. What two important kinds of cells in your body have to be replaced? How is this done?
6. What are the three stages in the reflex that cause the salivary glands to produce saliva?
7. How is a conditioned reflex developed?
8. Why do nerve cells get tired? How can they be rested?
9. What activities of the body are regulated by hormones?
10. For what purposes does the body need food?
11. In what ways are vitamins and hormones alike? In what ways are they different?
12. What is a balanced diet?
13. In what three ways can germs harm the body?
14. What natural defenses does your body have against diseases?
15. How are germ diseases different from other diseases?
16. How is it possible for the body to become immunized against disease?
17. In what ways can chemicals be used to control diseases?
18. What are the dangers of using alcoholic beverages?
19. What are the harmful effects of smoking?
20. How can a person avoid becoming a drug addict?
21. When does the critical period in the development of an organism occur?

B. WORDS IN SCIENCE

Write a sentence which tells how each pair of words listed below is related.

1. epithelium—mucous membrane
2. involuntary—reflex
3. impulses—neurons
4. dendrites—axons
5. tendons—ligaments
6. leucocytes—leukemia
7. brain—spinal cord
8. synapse—neuron
9. antibodies—antibiotics
10. toxin—toxoid
11. disinfectant—antibiotic
12. connective tissue—fatty tissue
13. nutrients—balanced diet
14. diabetes—insulin
15. toxin—antitoxin
16. homeostasis—automatic adjustment
17. sensory neuron—ganglia
18. reflex center—effector

You Can Go Further

A. BY REVIEWING THE HUMAN BODY

Six major kinds of activities that must be accomplished by the body are listed below. On page 540 are a number of different parts of the body. On your answer sheet, beside the letter of each part of the body, write the numbers of the activities with which they are primarily concerned.

ACTIVITIES OF THE BODY

1. Supporting itself
2. Carrying food to, and waste materials from, cells
3. Digesting food
4. Controlling its actions
5. Moving itself
6. Removing waste materials

PARTS OF THE BODY

a. Vertebrae
b. Spinal cord
c. Hinge joint
d. Bones
e. Ligaments
f. Muscles
g. Stomach
h. Nerves
i. Salivary glands
j. Blood
k. Sweat glands
l. Hormones
m. Pancreas
n. Plasma
o. Brain
p. Large intestine
q. Small intestine
r. Lymph
s. Kidneys
t. Lungs

B. BY REVIEWING THE CAUSES OF DISEASE

Five general causes of disease are listed below. Following them are the names of a number of diseases. On your answer sheet, beside the letter of the name of the disease, write the number of the general cause responsible for it.

GENERAL CAUSES OF DISEASE

1. Bacteria
2. Protozoa
3. Viruses
4. Diet deficiency
5. Improper functioning

Govt. of West Bengal

NAMES OF DISEASES

a. Diphtheria
b. Ulcers
c. Measles
d. Sleeping sickness
e. Scurvy
f. Mumps
g. Common cold
h. Rickets
i. Diabetes
j. Typhoid fever
k. Pellagra
l. Anemia
m. Smallpox
n. Malaria
o. Tuberculosis
p. Beriberi
q. Influenza
r. Infantile paralysis

C. BY EXAMINING HUMAN BLOOD

When biologists examine a living tissue such as blood, they mount it in a special solution on a microscope slide. Ringer's solution is a good one to use. You can make it by dissolving the following in one liter of distilled water: 0.42 grams of KCl, 9.0 grams of $NaCl$, 0.24 grams of $CaCl_2$, and 0.20 grams of $NaHCO_3$.

Blood can be obtained by pricking the tip of your finger with a needle which has been heated in a flame just before using it. You should also apply alcohol to your finger before and after you prick it.

Put a drop of your blood on a clean microscope slide. Add a drop of Ringer's solution. Place a coverslip over the slide. When you observe the blood under the microscope, you will see a great number of red cells. It will be more difficult to see the white cells. If you prepare another slide and place a drop of vinegar around the edge of the coverslip, you will be able to see the white cells much better.

D. By Testing for Vitamin C

From the Chemical Division of the Eastman Kodak Company, Rochester, New York, you can obtain a chemical indicator called ***indophenol*** (in-duh-FEE-nuhl). It is blue, but it bleaches when vitamin C (ascorbic acid), or juices containing ascorbic acid, are put into it. The solution of indophenol can be prepared by dissolving one gram of it in one liter of water.

Only 15 or 20 cc. of the solution are needed each time you make a test for ascorbic acid. Test different kinds of fruit and vegetable juices, both fresh and canned.

E. By Reading

Asimov, Isaac. *The Chemicals of Life.* New York: Abelard-Schuman, Ltd., 1954.

Provides an introduction to biochemistry with emphasis on enzymes, proteins, vitamins, and hormones.

Chandler, Asa C. *Introduction to Parasitology* (9th ed.). New York: John Wiley & Sons, Inc., 1945.

Comprehensive coverage, with emphasis on parasites of man.

Lorenz, Konrad Z. *King Solomon's Ring.* New York: Thomas Y. Crowell Company, 1952.

Presents interesting analyses of animal mind and behavior.

Riedman, Sarah R. *Our Hormones and How They Work.* New York: Abelard-Schuman, Ltd., 1956.

Story of the discovery and function of the hormones.

Sproul, Edith E. *The Science Book of the Human Body.* New York: Pocket Books, Inc., 1955.

Simple, well-illustrated book on anatomy and physiology.

Stanley, Wendell. *Viruses and the Nature of Life.* New York: E. P. Dutton and Company, 1961.

Presents a clear, basic account of viruses.

STATE INSTITUTE OF EDUCATION
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UNIT 10

Frontiers of Earth, Sea, and Space

When man thinks of frontiers, he usually thinks of unexplored and undeveloped places. The West was a frontier to colonists who settled along the eastern coast of America. Even after explorers had visited the West, it remained a frontier until it was settled and developed by pioneers.

It is estimated that intelligent man has been on the earth for about 50,000 years. In that time, he has encountered many frontiers—new lands, new seas, as well as the blanket of atmosphere surrounding the earth. The first attack on each frontier has been to explore it in order to find out what it was like. The second attack has been to find ways of developing it and of using it for human welfare.

This last unit in your textbook is a story of how science has been used to push back some of the frontiers of earth, sea, and space. It is a story that closes with speculation on what the future may be. No complete account can ever be written of man's ventures through science. As long as he asks questions, there can be no end to the frontiers which he must explore.

Woods Hole Oceanographic Institute

Lamont Geological Observatory—Columbia University

Oceanographic research vessel pulls in meter which has been measuring current in Gulf of Mexico. At right is ocean-bottom seismograph.

PROBLEM 1: WHAT ARE EARTH'S VANISHING FRONTIERS?

Before 1957, when the International Geophysical Year got under way, exploration and development of the earth had been pretty well limited to the thin outer crust of the earth and to the lower levels of its atmosphere. Some of the important things that have been learned about the atmosphere were discussed in Unit 7. However, the discussion there was limited to weather and climate. In Unit 7, it was stated that many facts about the atmosphere have been discovered, but the meteorologists are still trying to develop a theory that would explain the facts. Once this is done, the atmosphere will become a vanishing frontier.

So far in this book, the many facts which have been discovered through exploration of the outer crust of the earth have not been considered. It is in, and on, this part of the earth that human beings have carried out most of their exploration. Many things have been learned about it, and some of them will be discussed in this problem. But before going into the discussion of the earth's outer crust, the unit will take up some ideas about the formation and age of the earth and the methods that have been used in arriving at these ideas.

RECONSTRUCTING THE PAST

Have you ever been faced with the problem of trying to find out what happened when all you have to go on are a few clues? Investigators, such as detectives, frequently have to work with such problems. So must scientists who are interested in trying to find out what happened on earth long before anyone was here to observe the events. Under these circumstances, the scientist works with the evidence at hand. He collects the clues that relate to his problem and uses them in speculation about what happened.

Here is one example of how this problem-solving method works. Suppose you came upon a stalled truck with its warning flares burning. The truck had been hit by a car. You wonder why the driver of the car couldn't have avoided the accident by putting on his brakes. When you observe long tire skid marks leading to the wheels of the wrecked car, you decide that the driver of the car did apply his brakes. As a result, the tires slid.

You saw neither the brakes applied, nor the tires slide. You simply reasoned that *if* the tires made marks upon the pavement, *then* they must have been sliding. And that *if* the tires slid, *then* the brakes must have been applied.

You may further reason that *if* the skid marks are long, as they are, *then* the car must have been traveling fast. You conclude that the driver could not avoid the truck because he was driving too fast.

There are a number of precautions you must observe in using this *if-then* method. First, your original observations must be as accurate as possible. Second, the observations must be related to the problem. If, for example, the skid marks are later found to have been made by another car at another time, then the conclusion that the driver in this accident applied his brakes was wrong because of insufficient evidence.

It should be remembered, too, that conclusions reached by the indirect method cannot always be accepted as final conclusions. Additional study and observation may uncover facts which make it necessary to change the first conclusion and to formulate a different one.

EARTH'S AGE

One clue to the earth's age is the saltiness of the oceans. Assuming that the saltiness of ocean water is caused by salt brought in by rivers, it is reasonable to believe that, by dividing the total amount of salt in the oceans (estimated to be 4×10^{16} tons) by the additional amount brought in each year by rivers, the approximate age of the earth (1×10^{8} years) can be determined. The accuracy of this conclusion depends upon the accuracy of at least three *if* statements:

if the ocean has been accumulating salt since the beginning of the earth,

if this accumulation has taken place at the constant rate of 400,000,000 tons per year,

if all the salt in the ocean has been accumulated in this manner,

then the earth is at least 100,000,000 years old.

Scientists do not accept this estimate of the earth's age because the *if* statements involved are open to question.

Throughout much of the earth's history, the continents were probably quite flat. As a result, the rivers may have carried as little as one-tenth the salt they do today. When you take this into consideration, it is estimated that the oceans are about one-and-a-half billion years old. But even if the exact age of the oceans were known, it would not follow that the earth's age was the same.

When the earth was young, it was so hot that water probably could exist there only as steam.

It is probable that, for a long time, the earth was so hot that water could exist on it only in the form of steam. Only after years of cooling could the oceans have begun to form.

Another *if-then* estimate depends upon the behavior of radioactive elements. ***Uranium*** and ***thorium*** are two such elements found in rocks. Both these elements pass through a series of changes and finally become ***lead***. The time required for this process is known, and it seems to be independent of outside factors. Thus:

if a rock is as old as the earth,

if the rock originally contained no lead such as that coming from the breakup of uranium,

then the earth is as old as the time required to form, from uranium, the lead it now contains.

Scientists have estimated the age of rocks from many parts of the world by measuring the amounts of uranium and lead in them. At this time, scientists believe that the age of the earth is somewhere between five and six billion years.

THE EARTH'S CRUST

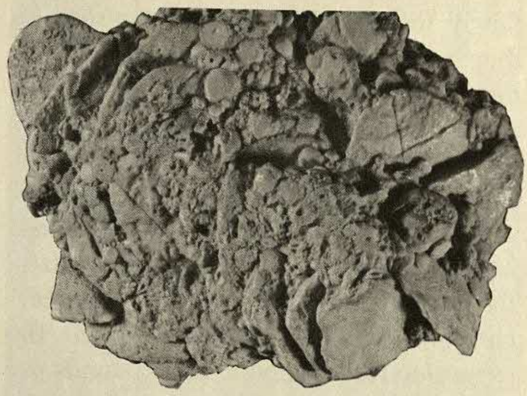
The crust of the earth shown in the diagram on page 287 is only twenty-five miles thick. From the earth's surface to its center is about 4,000 miles. If you used a classroom globe eighteen inches in diameter to represent the earth, the crust would be represented by a thin covering less than one-sixteenth of an inch thick.

Although the earth's crust is only twenty-five miles deep, only the upper one-fifth of it has been probed by our deepest oil well. You can see why it would be proper to say that the earth's crust has hardly been scratched by man's exploration of it. But the scratching has given him a great deal of information about the earth's crust. It has also given him clues about how it was formed.

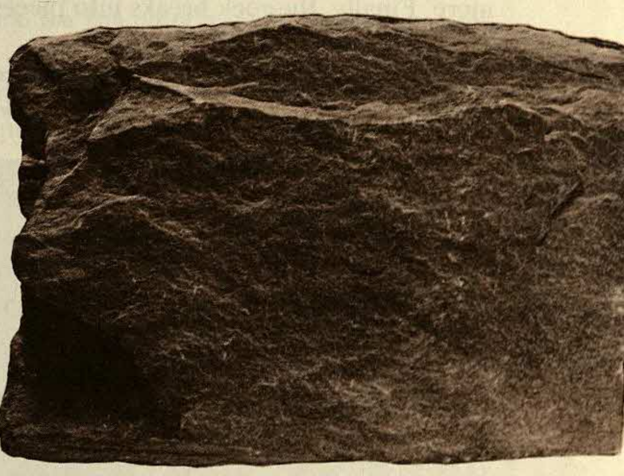
It is thought that at one time the earth was very hot. As it slowly cooled, a solid crust began forming. Further cooling increased the crust's thickness, but it also caused the earth to shrink in size. Thus, the outer crust folded and wrinkled, much as skin does on fruit when it dries. This action formed the original mountains and valleys of the earth. From that time, the earth's crust has been undergoing constant change. Scientists call the crust the ***lithosphere.*** The rocks that make up the lithosphere are classified according to their origin, and are called ***igneous, sedimentary,*** and ***metamorphic.***

Weathering of Igneous Rocks

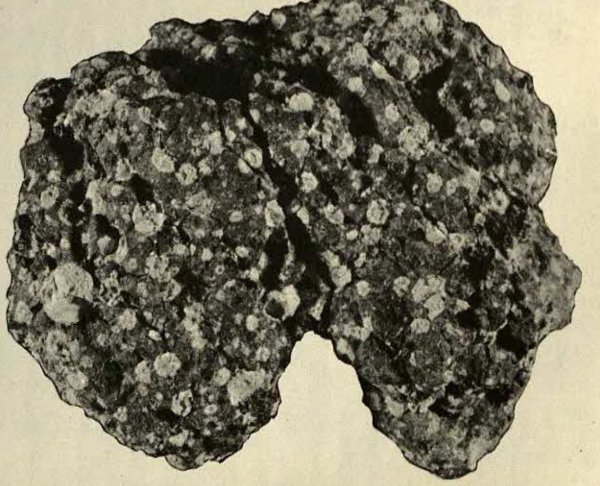
Igneous rocks, such as granite, were formed when molten material from deep within the earth came to the surface, cooled, and hardened. Igneous rocks begin



Limestone, top, encrusted with shells, is an example of a sedimentary rock. Black slate, center, is a metamorphic rock formed when soft shales and clays hardened. Basalt, bottom, is an igneous rock produced by a lava flow.



Three photographs by American Museum of Natural History



slowly to break and crumble as soon as they are formed. The process by which rocks are broken down is known as ***weathering.***

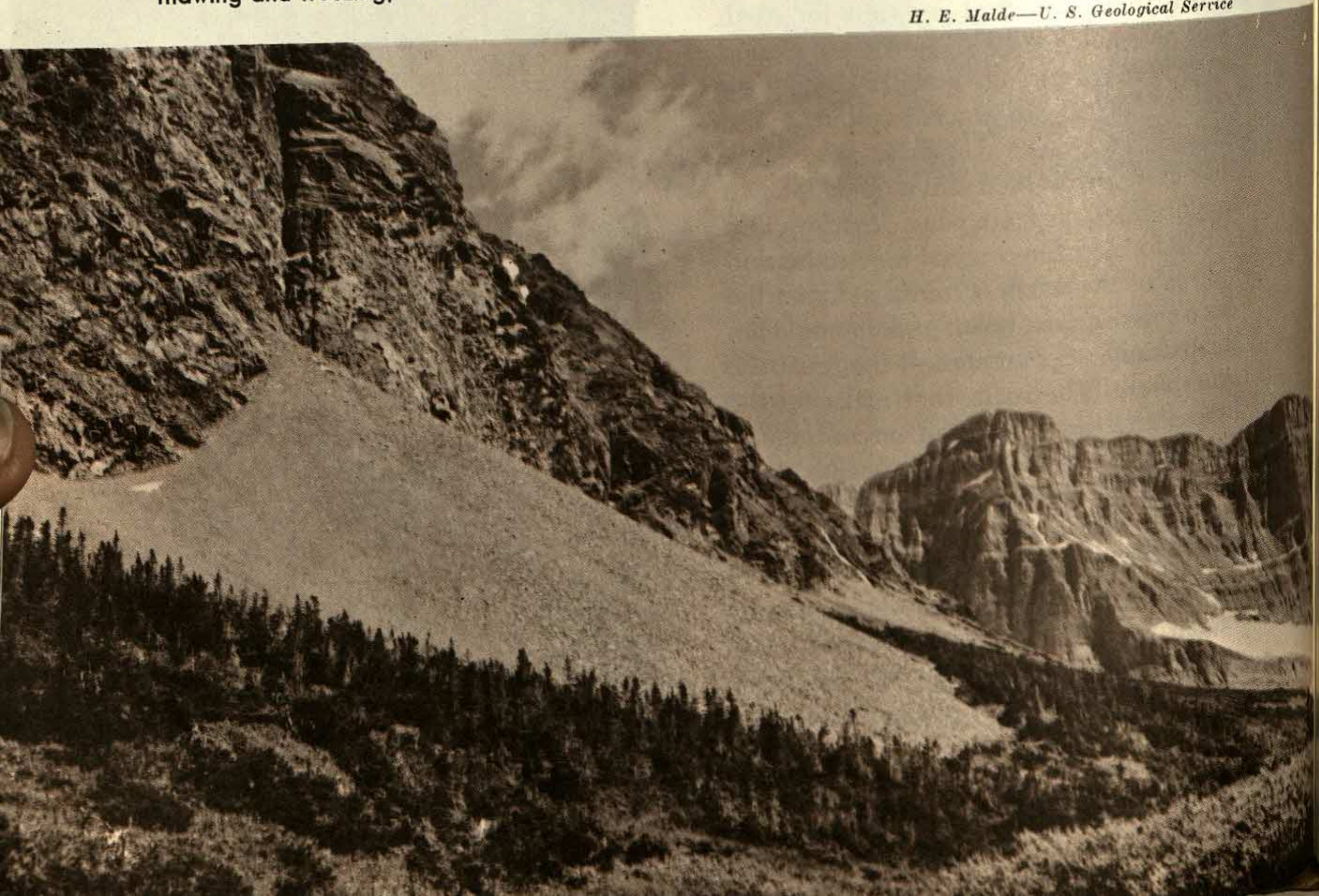
One of the most powerful forces of weathering is the alternate freezing of water and thawing of ice. Water seeps into the pores of a rock. When it freezes, the water expands as much as one-eleventh of its size. At the freezing point, the expansion force is about 2,000 pounds per square inch. At 8° below zero, this force increases to 34,000 pounds per square inch. This tremendous force expands the rock slightly. Each time the ice melts and freezes again, it spreads the rock a little more. Finally, the rock breaks into pieces.

Plan a way to use the freezing tray in a refrigerator to measure how much water expands when it freezes. How can you indicate the depth of water in the tray before it is put into the refrigerator? How can you indicate the depth of ice after it has frozen? How could you tell if it expanded one-eleventh of its size upon freezing? Several pupils should experiment at home. Compare results.

Pioneers in Salt Lake City, Utah, during the winter, used water to break up large blocks of granite, which they used in their buildings. Explain how they may have done this.

Pile of rock at base of cliff is known as talus cone. Rock was broken from face of cliff by alternate thawing and freezing, and then moved downward by action of gravity and running water.

H. E. Malde—U. S. Geological Service



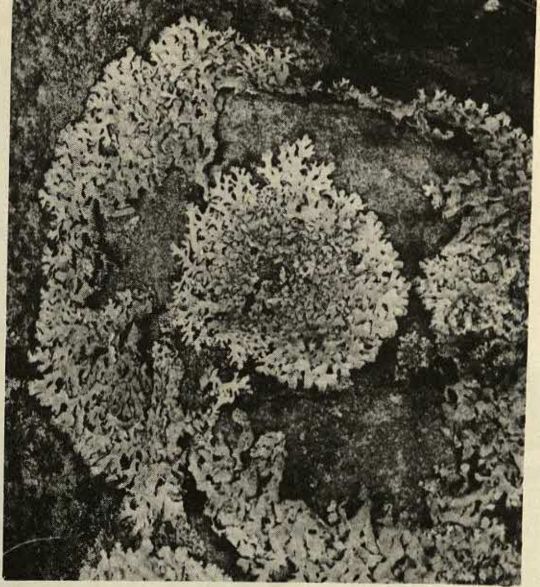
Soil Formation

Most soils are built up by plants from the rocky materials on the surface of the earth. The first plants to appear on a rock are dry, flat, crust-like structures called lichens, which form greenish patches on rock. As parts of the lichens die, bacteria causing them to decay gives off carbon dioxide gas. When it rains, the carbon dioxide dissolves in the small amount of water that collects around the lichens and forms a chemical compound, carbonic acid (H_2CO_3).

Test some soda water with litmus paper. Because it is an acid, it will turn blue litmus paper pink. Soda water is a weak solution of carbonic acid. Pour some of it on pieces of limestone. You can see that it reacts with limestone.

Carbonic acid slowly dissolves calcium carbonate out of the rocks containing it and causes them to crumble into smaller particles. This weathering of rock by lichens is very slow, but, in time, small depressions are formed, in which rain water and the remains of lichens collect.

Other types of plants, such as moss, may begin to grow there. As the moss grows, weathering of the rock continues, and the depressions little by little become deeper. The decaying remains of moss plants also become mixed with the rock particles. It is the mixing of rock particles with organic matter from many sources that gradually forms soil.



American Museum of Natural History

Lichens growing over rocks help break rocks into the fine particles which later become soil.

As the soil becomes deeper, other types of living things grow in it. Gradually more bacteria, worms, insects, and other small animals find this newly formed soil a suitable home. Roots from larger plants spread throughout the soil. Some of them grow into cracks in the rocks and force the rocks farther apart. Worms and insects burrowing through the soil help to mix the organic material with the rock particles. Bacteria continue to decompose dead plants and animals. As all this activity continues, more rock is weathered and mixed with organic material to form soil. The soil-forming process slowly penetrates deeper and deeper into the earth.

If there are woods near your school, visit them. Find the places where large rocks have been partly covered by soil. Remove some soil from around the base of the rock. Compare the brittleness of the rock below the soil with the rock above the soil by tapping it, or picking at it, with a hammer.

Wind is a powerful weathering agent. It produced this huge sandstone arch in southeastern Utah.

Utah Dept. of Commerce

As you will remember, running water and glaciers break larger rocks into smaller pieces. When water penetrates into cracks and freezes, the expansion of the ice may break the rock. Wind carrying fine particles of rock may wear away larger rocks. All these forces aid in the formation of soil.

> **Concrete is a man-made rock. Look for places on concrete sidewalks where the concrete has been weathered. Find places where the sidewalk has been cracked by ice.**

Topsoil and Subsoil

The soil of the earth is divided into layers—***topsoil*** and ***subsoil.*** In most places, the topsoil at the surface is the older soil. You can see why this would be true if the soil had been formed from the rock beneath it. Scientists who study soils estimate that it takes from five hundred to a thousand years to form one inch of good topsoil. In some places, the topsoil is only a few inches deep. In other places, it is several feet deep. The soil underneath the topsoil is called subsoil.

Topsoil is more fertile than subsoil because it contains more of the minerals plants need for growth. The value of land for farming is determined largely by the depth of its topsoil. Though subsoil is younger and less fertile than topsoil, it supplies many of the materials needed by plants whose roots grow deep.

Topsoil may be transported several hundred miles from the place where it was formed. Winds blowing over dry, unprotected land pick up the soil and carry it away. It is washed into rivers by rain water. When the rivers overflow and flood the land, they deposit this soil. Such soil is generally very rich because it is the topsoil from land farther up the river.

Visit a place where a hole has been dug deep enough into the ground to expose both the topsoil and subsoil. Fill a gallon can with topsoil and another with subsoil. Take the cans of soil back to your classroom for examination.

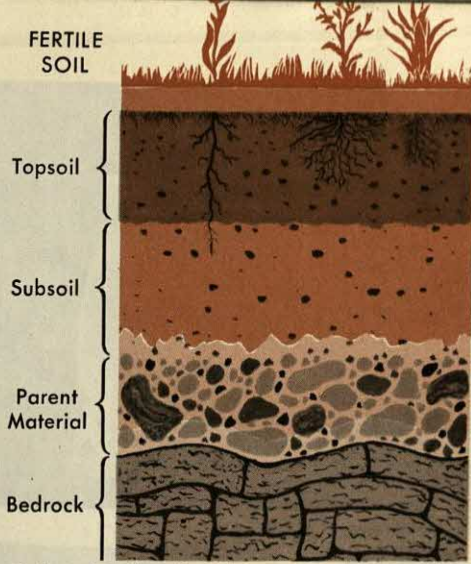
Describe the color, odor, and texture of each soil. Why are they different? Now spread each can of soil on a newspaper. Count the number of animals that you can find in each can of soil.

Fill two or more flowerpots with each kind of soil and plant bean seeds in each. Keep the pots well watered. Compare the growth of bean plants in each kind of soil.

Sedimentary Rocks

Soil may be moved about by the combined action of wind, water, and gravity. Eventually it will be dropped by the carrying agent to form large beds of ***sediment.*** When the sediment is dropped by flooding rivers, it may form rich farm land. In the ancient seas, the sediment became cemented together by a process not well understood. It hardened and formed sedimentary rock. ***Sandstone, shale,*** and ***limestone*** are common sedimentary rocks of this type. Can you tell what kind of sediment formed each kind of rock?

Four-fifths of the total land surface of the globe is made up of sedimentary rocks. In the walls of the Grand Canyon, they are exposed to a depth of 4,000 feet. They also form the towering cliffs and peaks of Glacier National Park. Oil wells are drilled into sedimentary rock 25,000 feet beneath the earth's surface.

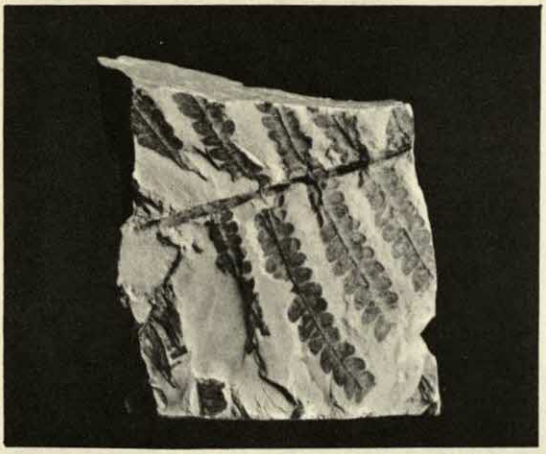


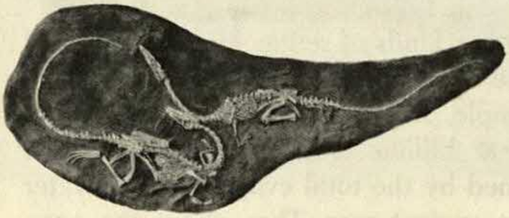
Other kinds of sediment, in addition to those discussed above, are also found. For example, salt beds, estimated to contain 30,000 billion tons of salt, have been formed by the total evaporation of water from ancient seas. Throughout the ages, the seas were populated with tiny plants and animals. Their life processes were responsible for the formation of calcium carbonate ($CaCO_3$) which, together with the solid parts of their bodies and the shells of larger sea animals, were laid down in vast deposits that eventually formed limestone, a sedimentary rock.

Sometimes the remains of plants and animals living during a period of sedimentation are preserved so well in the sedimentary deposits that their forms can be seen clearly. These remains are called ***fossils.*** Scientists called ***paleontologists*** study these fossils to determine what kinds of plants and animals lived on earth.

FOSSIL FUELS

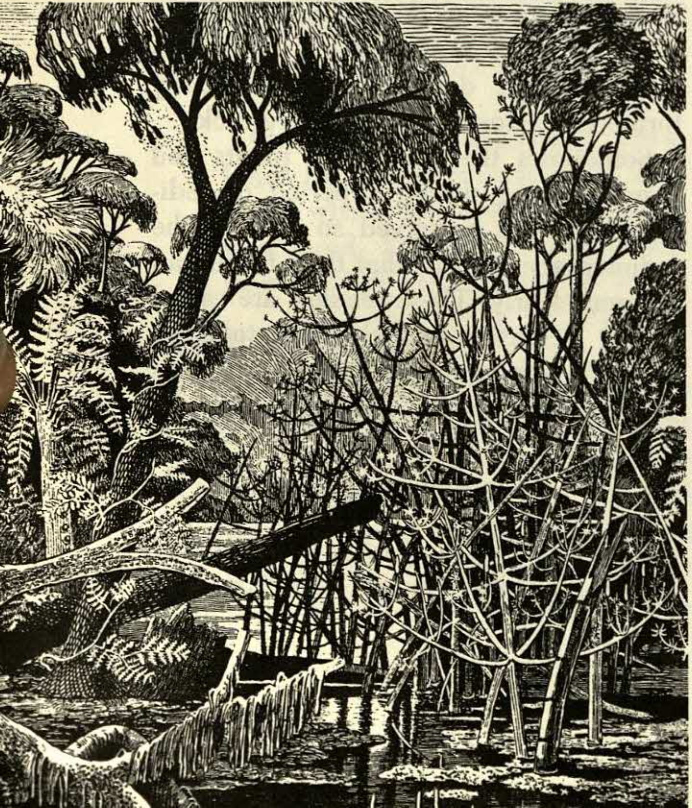
About ninety-two percent of the energy used in the United States comes from coal,





In coal you can sometimes see fossil fern, top, or animal, center. Such plants and animals were found in Carboniferous forests, bottom.

Three photos by American Museum of Natural History



petroleum and natural gas. These are *fossil fuels*, which took millions of years to form. Although they may now be forming at certain places on the earth, they are forming so slowly that man must depend upon the present deposits for his supply.

Coal, oil, uranium, and other materials which require millions of years to form are called ***fixed resources.***

There is every indication that the rate at which the earth's materials are being used will increase rather than decrease. One scientist, taking into consideration the probable increases in standard of living and population, estimates that the supply of coal will last 2,000 years. Petroleum and natural gas in the United States may last 160 years. Although unforeseen factors may make the fuels last longer, it seems certain that unless new sources of energy are discovered and put to use, the fossil fuels will one day be exhausted. For this reason, you will probably see an increasing use of atomic and solar energy.

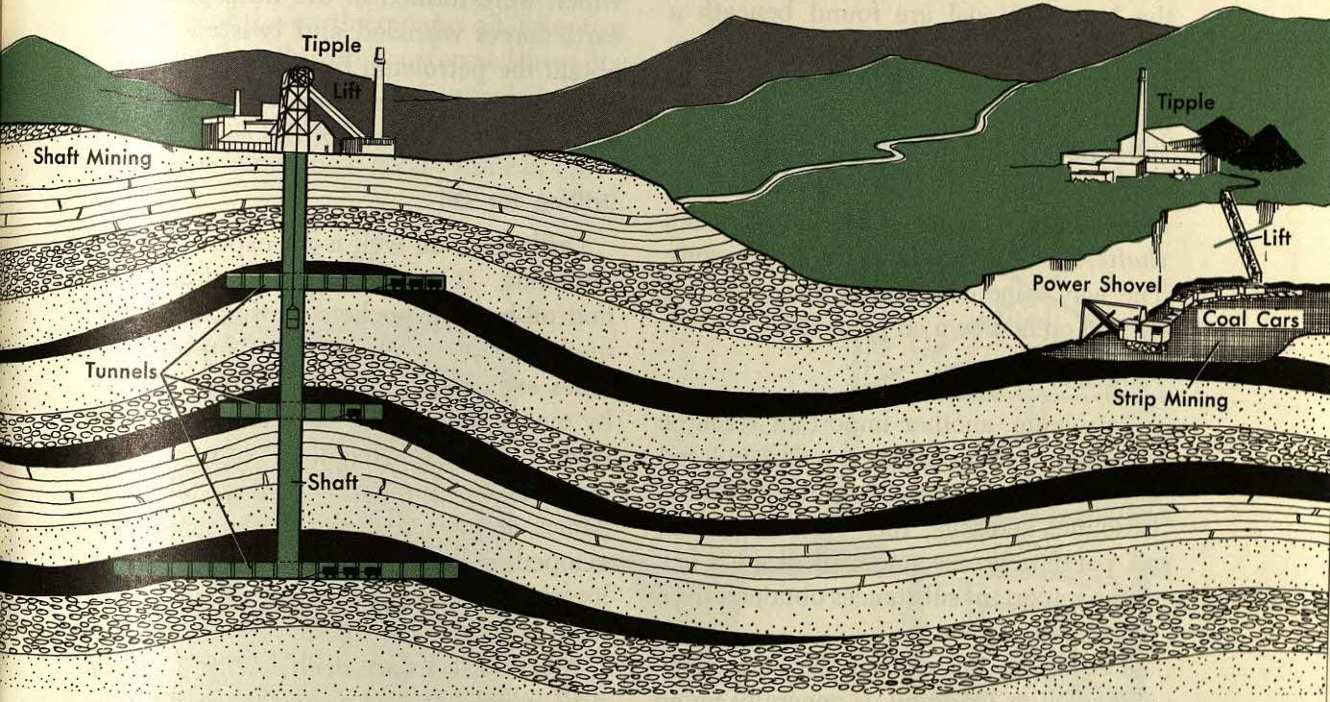
Formation of Coal

Since no one has been able to observe coal being formed, scientists have attempted to explain its formation by the *if-then* method. The following facts were discovered by direct observation:

1. Coal contains carbon, hydrogen, oxygen, nitrogen, sulfur, and some mineral substances. Many of these chemical elements are also found in plants.

2. Coal often contains imprints of leaves of giant tree ferns similar to those found in tropical jungles today.

3. ***Methane gas,*** called ***firedamp,*** is often found in coal mines. When plants



To reach buried coal veins, shown at left, a deep shaft is dug. Tunnels supported by pillars extend out from the shaft to enable miners to get more coal. If the coal is near the surface, as at right, the soil is stripped off with power shovels and the coal is exposed.

decay in marshes or bogs, methane gas is formed.

4. Thin slices of some kinds of coal look very much like thin slices of plants when examined under a microscope.

Scientists have said that *if* the above facts are true, *then* it can be concluded that coal was probably formed from plants which grew in a tropical climate.

Other observed facts about coal are:

1. Coal is found in layered deposits, or ***seams,*** often called ***veins.***

2. Coal is found near shale, sandstone, and limestone, all sedimentary rocks.

3. The largest coal-bearing regions of the earth are located where it is believed that swamps once existed and were later buried under sediment.

4. Plant materials have been put under high pressure and temperature in the laboratory and have been changed into a black substance which closely resembles coal.

Scientists again said that *if* these facts were true, *then* it could be further concluded that plants were probably buried under sediment and, as a result of slow decomposition, were changed to coal.

Coal Mining

Coal is mined in various ways. Where the layers of coal are found beneath a shallow layer of soil, ***strip mining*** is done. How is it possible that coal could be so near the surface? Much coal lies at a considerable depth below the surface in seams varying from a few inches to about sixty feet in thickness. Deep holes, called ***shafts,*** are dug down to the coal seams. The way some coal mining processes are carried on is shown on page 553.

Petroleum

Petroleum, another important resource obtained from the earth, is a dark-colored oily mixture of many different substances. Gasoline, kerosene, fuel oils, lubricating oil, paraffin, grease, and asphalt are a few of the important substances obtained from petroleum.

Petroleum, taken from the earth, usually as oil or ***crude oil,*** is generally found in sedimentary rocks. Salt water and materials from plants and animals that lived in the sea are often found with it. These facts have led scientists to conclude, by the *if-then* method, that petroleum was formed from the plant and animal life of the sea. The process by which it was formed is not entirely understood. It seems probable, however, that great pressure and high temperature played a part.

Natural gas is also produced in the petroleum-forming process and is often found with it in the earth.

Because the sedimentary rocks, such as sandstone, have a ***porous,*** or sponge-like, structure, petroleum, gas, and sea water accumulated in them and moved upward through them much as ink moves along a blotter. These substances became trapped in dome-shaped structures, or pockets, which were formed in the lithosphere as earth forces wrinkled and twisted it. To obtain the petroleum from these pockets, wells must often be drilled thousands of feet below the surface of the earth.

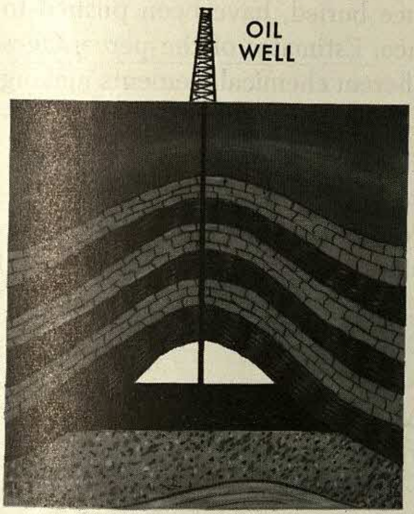
Drilling for Oil

Drilling an oil well is an expensive undertaking. It is, therefore, desirable to find oil-bearing pockets in the earth before drilling a well. At first, and sometimes even today, men tried to locate oil by means of ***divining rods*** and other devices of magic. Needless to say, such methods are unreliable. Today, oil companies employ geologists, who have developed reliable scientific methods of locating rock formations in which petroleum is likely to be found.

Most oil wells are drilled with a ***rotary drill,*** which bores a hole in the earth somewhat as a bit bores a hole in wood. The rotary drill is hollow. As it is twisted down into the earth, a constant stream of mud is forced through it. The mud keeps the drill cool, prevents cave-ins by covering the sides of the hole, and carries the rock cuttings from the drill up to the surface. As the hole is drilled, a steel pipe called a ***casing,*** is forced into it. When the oil-bearing material is finally reached, a smaller pipe is lowered into the well. This pipe is sealed to the casing at the top so that the oil cannot escape except through the small pipe. Valves to control the flow of oil and ***gauges*** to measure the pressure and amount of oil flowing through the casing are attached to the smaller of the two pipes.

Shale Oil

Much of the shale now exposed on the surface of the earth contains oil. Scientists believe that this oil was formed from the bodies of tiny plants and animals trapped in the mud that later became shale. Shale may, therefore, be a good source of oil.

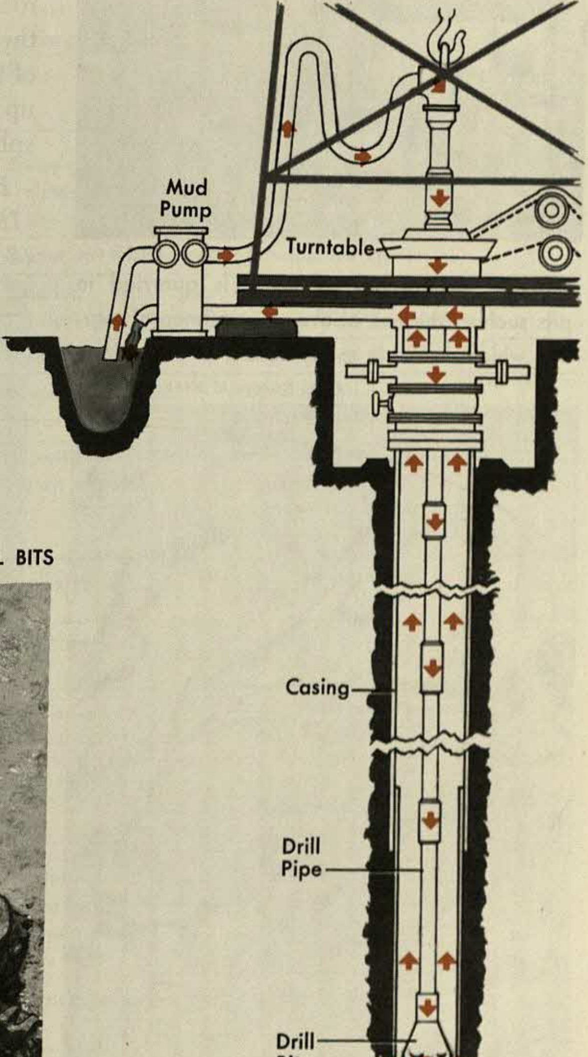


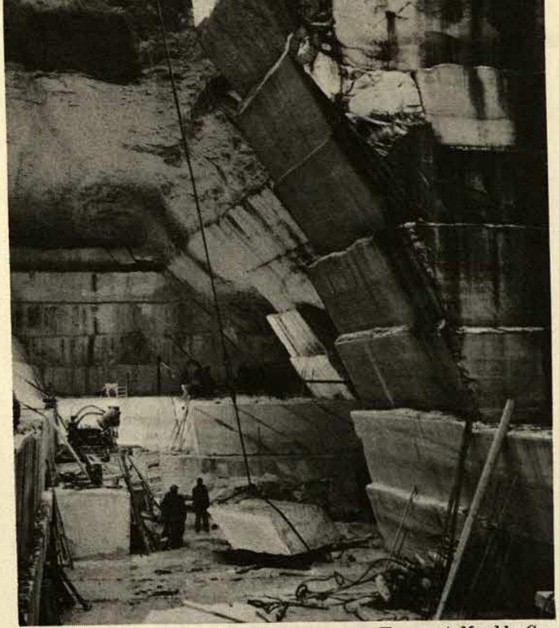
Standard Oil Co. (N. J.)

DRILL BITS

METAMORPHIC ROCKS

Rocks are sometimes acted upon by heat and pressure in a manner that changes their original character. Such changed rocks are called metamorphic rocks. Two examples are marble, which is





Vermont Marble Co.

Marble, a metamorphic rock, is quarried in pits such as the one above. A specimen of marble, which comes in many colors, is at bottom.

U. S. Bureau of Mines—U.S.D.I.

metamorphosed, or changed, from limestone, and slate, changed from shale.

Chemical Composition

To determine the amounts of chemical elements in the lithosphere, scientists have studied thousands of rock samples taken from deep wells, mines, and places where rocks, once buried, have been pushed to the surface. Estimates of the percentages of the different chemical elements making up the outer ten-mile layer of the lithosphere are shown in the table below.

Elements in Order of Their Abundance in The Outer Ten-Mile Layer of the Lithosphere
(Based upon studies of Clarke and Washington)

Element	*Percent*
1. Oxygen	46.71
2. Silicon	27.69
3. Aluminum	8.07
4. Iron	5.05
5. Calcium	3.65
6. Sodium	2.75
7. Potassium	2.58
8. Magnesium	2.08
9. All others	1.48

Most of the elements in the lithosphere are found in combination with other elements. Among the few pure elements are copper, gold, silver, and sulfur.

Some of the more important compounds, together with their chemical formulas, usual appearance, and uses, are shown in the table of common ***minerals*** on page 557. A substance found in the lithosphere, which has a uniform chemical composition and was never a living thing, is known as a mineral. Thus the elements and compounds listed above and in the table occur as minerals.

Some Common Minerals

Name	Formula	Appearance	Uses
1. Bauxite	$Al_2O_3 \cdot H_2O$	White, red, brown, yellow	Most common ore of aluminum
2. Calcite	$CaCO_3$	White or colorless; with impurities, gray, red, green blue; bubbles when touched with acid (HCl or vinegar)	In manufacture of lime, plaster, cement; chief component of limestone and marble
3. Carnotite	$K_2O \cdot 2UO_3 \cdot V_2O_5 \cdot 2H_2O$	Yellow	Ore of uranium
4. Chalcopyrite (Copper Pyrites)	$CuFeS_2$	Brassy yellow; if tarnished, dark with rainbow hues	Valuable ore of copper
5. Cinnabar	HgS	Scarlet to brownish-red	Principal ore of mercury
6. Feldspar (Orthoclase)	$KAlSi_3O_8$	Colorless, white, pale yellow, gray pink, red	Used in manufacture of porcelain
7. Galena	PbS	Lead gray to black	Chief source of lead
8. Gypsum	$CaSO_4 \cdot 2H_2O$	White, yellow, red, brown, black	Used for production of plaster of Paris
9. Halite (Rock Salt)	$NaCl$	Yellowish, reddish-black, gray, or black	Used in cooking; a preservative; used in chemical industry; ordinary table salt
10. Hematite	Fe_2O_3	Steel gray, black	Most abundant ore of iron
11. Magnetite	Fe_3O_4	Black	Valuable iron ore; magnetic
12. Olivine	$(Mg,Fe)_2SiO_4$	Olive or grayish to yellowish brown, green	When transparent, may be used as gem
13. Pyrite (Fool's Gold)	FeS_2	Brassy to gold, yellow	One source of sulfur in manufacture of sulfuric acid
14. Quartz	SiO_2	Colorless to white—many varieties colored by impurities	As ornamental stone; as abrasive; in manufacture of glass, porcelain; in paints
15. Serpentine	$H_4Mg_3Si_2O_9$	Gray to green or brown	May be used as building stone
16. Sphalerite (Zinc Blende)	ZnS	White, yellow, brown, or black	Most important source of zinc

Fossils of sea animals have been found in rocks on top of mountains. How did these animals get there? Many rocks that now form mountains were once covered by the sea. It may seem incredible to you that high mountains were once beneath the sea. In your lifetime you will see little, if any, drastic changes in the features of the earth. You must remember, however, that a lifetime of seventy years is extremely short when you consider the fact that the earth has probably been in existence more than seventy million lifetimes. Continuous gradual change over billions of years has produced the earth as modern man knows it.

Erosion of Land

After a hard rain, you can see tiny streams flowing downhill over sloping land. Closer examination will show that these streams are carrying sand, gravel and other bits of materials. Suppose that these streams were thousands of times bigger. They would then be raging flood waters capable of moving gigantic rocks weighing many tons.

Moving water is one of the most active agents of ***erosion.*** When erosion takes place, the material that results from weathering is carried away. It is estimated that the Mississippi River alone carries about half a billion tons of material into the Gulf of Mexico each year. Much of the material is good farm soil.

Continuous action of ocean tide and surf and occasional violent storms break down sea cliff walls, grind the rock finer and finer, and eventually move it seaward.

Make a survey of the area around your school and home to find places where run-off water has eroded the land. What can be done to slow down the run-off?

After a rain, collect a gallon of run-off water from one of these places. Separate the sediment from the water by allowing it to stand. After the sediment has dried out, weigh it to find out how much solid material was carried in a gallon of water. If this is done for several places, you can make some interesting comparisons.

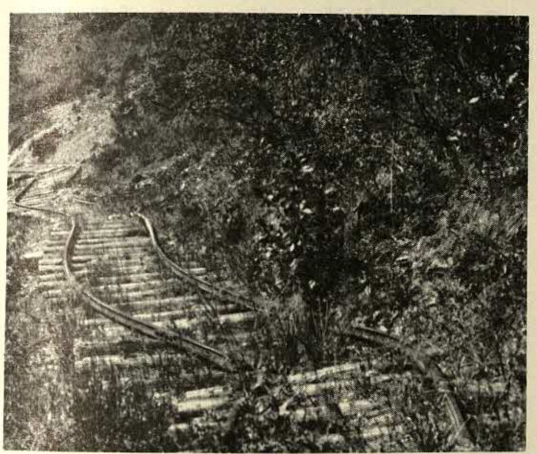
Mass Wasting of Soil

The soil on a slope slowly moves downhill under the continuous pull of gravity. This slow movement is known as ***creep.*** On one slope along which a railway was built, the soil moved from six to ten feet in fifty years. This movement of the soil necessitated frequent repair of the railroad roadbed.

Sometimes, large masses of earth slide suddenly down a slope and cause a landslide. In 1903, at Frank, Alberta, Canada, some 40,000,000 cubic feet of rock broke away and came roaring down the mountain into a valley 3,000 feet below. The rock spread in a sheet across the valley, wiped out the town of Frank, and killed seventy people.

In these types of erosion, known as ***mass wasting,*** gravity is the moving force. How is this different from erosion by water? Geologists believe that, given sufficient time, mass wasting alone would eventually reduce the continents to smooth plains.

SOIL EROSION

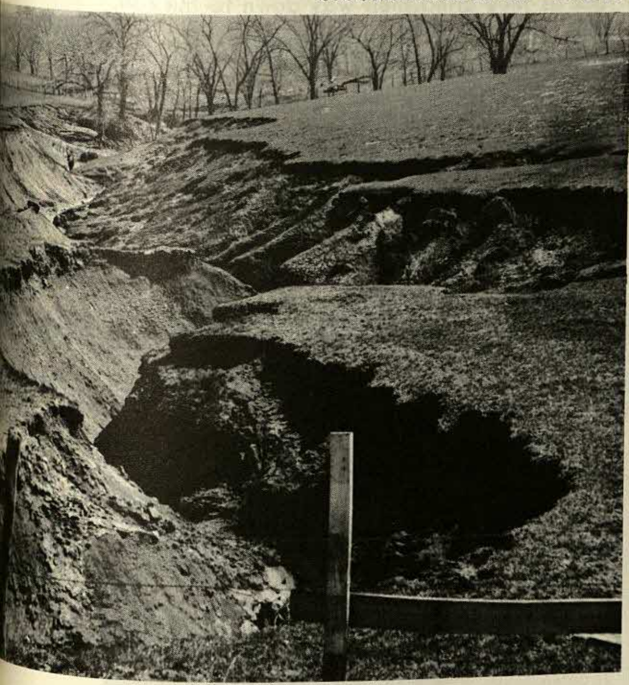


U. S. Geological Survey—W. W. Atwood

Railroad tracks, above, are being covered by mass wasting, or creep, of soil down slope.

Heavy rains on bare slopes produced these deep gullies, which are slowly destroying fields.

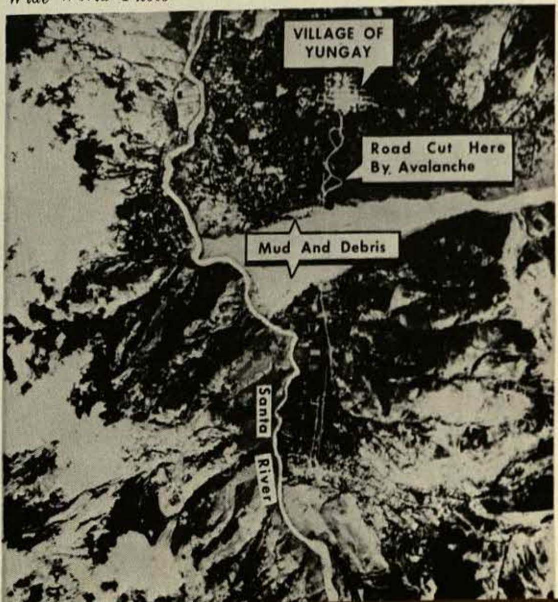
Soil Conservation Service—U.S.D.A.



Tides and pounding waves are slowly wearing down rocks along Pacific coast.

Avalanches such as the recent one in Peru, shown below, move tons of snow, ice, and rock down mountains.

Wide World Photo



Glaciers

In regions where the climate is cold, more snow may fall than melts. The snow piles up, and, under the influence of moisture and pressure, the lower part of the snow mass changes to ice. When the mass becomes deep enough, usually 100 to 150 feet, it begins to creep slowly downhill in the form of a ***glacier***.

Moving glaciers are powerful agents of erosion. They dislodge large chunks of rock and transport them downhill. You may live in a place where you can see rocks that glaciers left behind. You may also see where glaciers carrying rock scraped over larger boulders and left deep scratches.

Some glaciers flow down mountain canyons. Others take the form of large ice sheets such as those found today in the polar regions. I.G.Y. scientists measured ice 14,000 feet thick in Antarctica.

Geologists believe that most of Canada and the northern part of the United States were, at one time, covered by a huge ice sheet. This moving ice sheet was probably responsible for the thousands of lakes throughout northern United States and Canada; for the large boulders strewn over the surface of New England and eastern New York; and for the present location of both the Ohio River and the upper Missouri River.

Wind Erosion

Wind not only moves quantities of soil in sand and dust storms, but it also wears away exposed rocks by blowing sand against them. The rock formations on page 550 were produced by wind erosion.

Great glaciers, such as the one below, carry tons of rock as they grind their way down to the sea.

Canadian Film Board

OTHER MOVEMENTS OF THE EARTH'S SURFACE

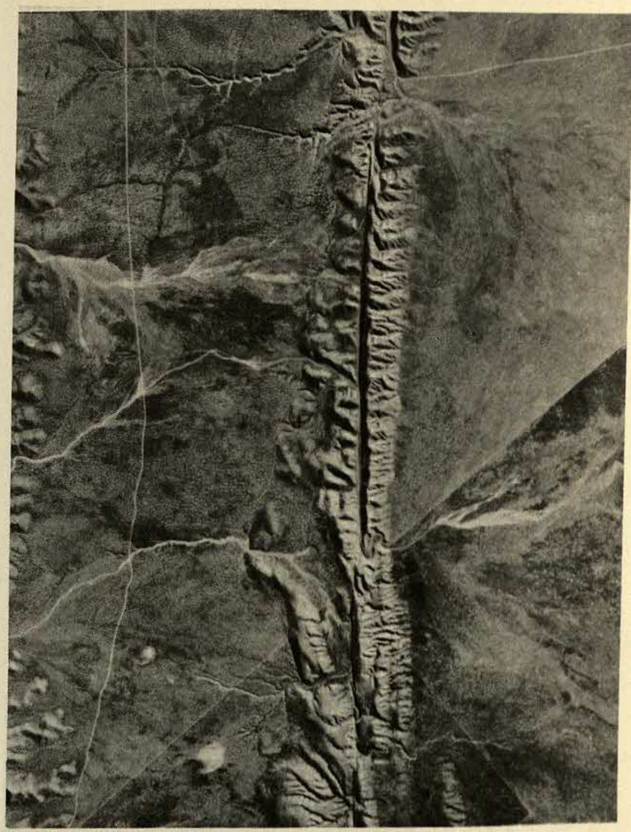
Although man likes to think of the earth as "terra firma," there is considerable evidence to show that large portions of the land move slowly up or down. This movement sometimes increases, or sometimes decreases, the land area.

Tremendous internal pressures, the source of which is not fully understood, cause the surface to bend, fold, and sometimes to break open. On each side of the break there is a sudden shifting of the earth. Movement of the earth's crust, whether vertical or horizontal, is known as ***diastrophism*** (di-AS-truh-fizm).

Vertical Changes

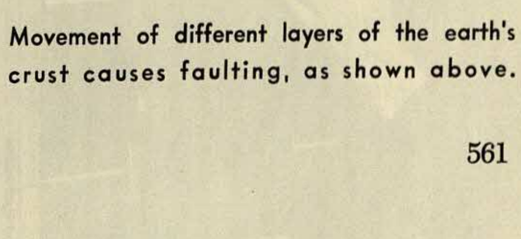
Marks placed along the shore of the Baltic Sea show that the countries bordering it are slowly rising. In some places, the rise is as much as three feet in a hundred years. It is thought that parts of Sweden and Finland are as much as 900 feet higher than they were at the end of the last ice age 25,000 years ago. It is believed that many of the islands off the Maine coast are hilltops of former land surfaces. They became islands when the land sank and allowed the sea to flood existing river valleys.

A large-scale vertical change is presently occurring in the Great Lakes region of the United States and Canada. Measurements show that the land to the north and northeast of the lakes is rising five inches per 100 miles each 100 years. If this rise continues, in some 1,600 years the lakes will flow to the ocean by way of the Chicago and Mississippi rivers instead



Fairchild Aerial Surveys

Aerial view clearly shows San Andreas fault in California. Shock waves caused when its rocky slides slid past each other killed hundreds of people and shifted the course of river beds.



Movement of different layers of the earth's crust causes faulting, as shown above.

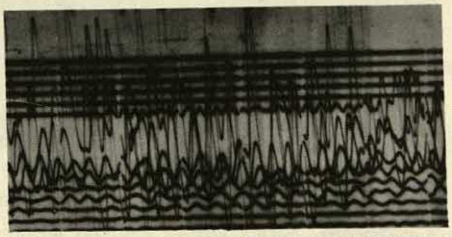
of by way of the St. Lawrence as they do at the present time.

Earthquakes

The rocks in the lithosphere are not a solid mass. They have cracks through them in many directions. When pressure on a layer of rock becomes great, part of the layer on one side of the crack may slip past the other and thus form a ***fault.*** Formation of new faults, or further sudden slipping along old faults, is one of the major causes of ***earthquakes.*** An earthquake is a vibration of the lithosphere, which is started by some sudden jarring, much like the vibrations of a bell after being struck by a sharp blow. The ground suddenly shakes, buildings fall, and, in cities, gas and water lines break. Frequently fires break out. Many people are killed, or left homeless.

The great earthquake in Tokyo, Japan, on September 1, 1923, killed some 140,000 people and resulted in property damage of about three billion dollars. One scientist has estimated that at least thirteen million people have been killed by earthquakes in the course of four hundred years. It is no wonder, then, that man considers earthquakes among the greatest of natural disasters.

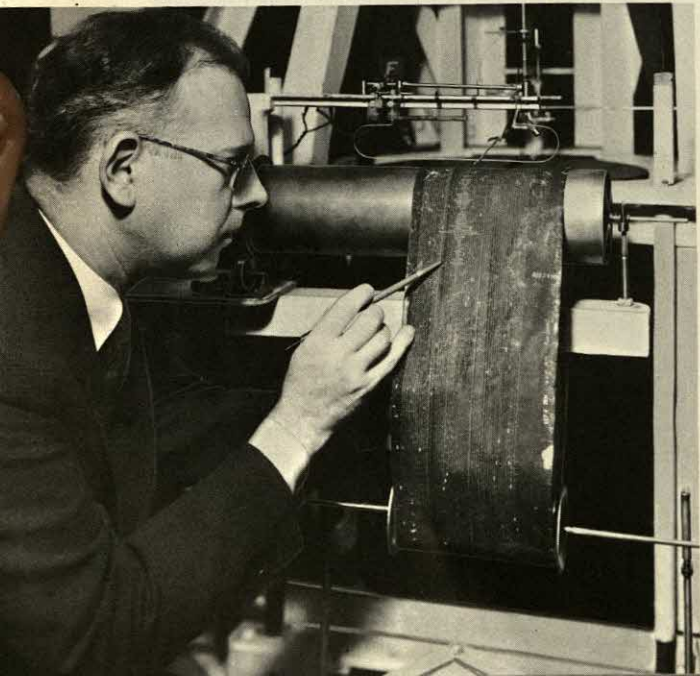
Although it is well known that earthquakes are associated with volcanic activity, the major earthquakes result from

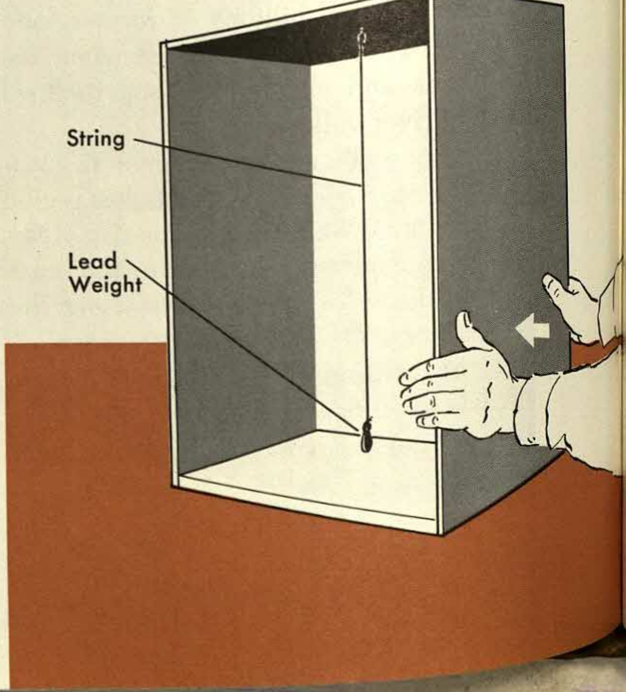


Fordham News Service

Instrument below, left, called a seismograph, records vibrations of earthquakes by tracing lines on a drum. Seismograph record of an earthquake in India in 1951 is shown at top.

American Museum of Natural History





faulting. The great San Andreas fault, which can be traced along the earth's surface for 600 miles, passes near San Francisco. A sudden movement along this fault, as much as twenty-one feet in some places, caused the disastrous San Francisco earthquake on April 18, 1906.

If you place a small rock on a board on the floor and strike the board a sharp blow with a hammer, the rock will travel many times the distance the board moves. In a similar manner, objects on the earth's surface may be thrown several feet by the passing of a vibration from an earthquake, even though the ground actually moves only a fraction of an inch.

Scientists record vibrations from earthquakes on an instrument called a ***seismograph*** (SYS-muh-graf). Seismograph records show that earthquake waves travel great distances through the earth's crust before they die out. One method of determining the structure of the earth's interior by the *if-then* method is a study of records from various parts of the world.

You can show how a seismograph works by hanging a lead weight inside a box, as shown in the diagram. When this box is moved, the lead weight at the end of the string tends to remain still.

In a seismograph, the box, or frame, is attached to bedrock. When there is a slight movement of the rock, the apparent movement between the frame and weight is recorded by a pen.

Although much is known about the causes and effects of earthquakes, the conditions necessary for them to occur are so complicated that little hope is held out that seismologists will be able to predict their coming with accuracy. Our best protection seems to lie in constructing buildings which will withstand the shock, and in taking precautions to safeguard lives and property.

Volcanoes

The smallest volcano is no larger than a beehive. The largest is the massive 19,882-foot ***Guallatire*** (gwah-yah-TEE-ray) in Chile. Many well-known peaks in the United States have been volcanoes. Mt. Baker, Mt. Rainier, and Mt. Hood in the Cascade Range in the western part of the United States are extinct volcanoes.

There are several hundred active volcanoes in the world today. The United States formerly had only one active volcano—Mt. Lassen in California. With the admission of Alaska and Hawaii as states, more than thirty were added.

Volcanoes may eject gases, molten rock called ***lava***, and solid material. Steam is usually given off in huge quantities and is probably the greatest part of the gaseous eruption. It is estimated that Paricutin (pah-REE-koo-teen), a volcano formed in Mexico in 1943, discharged about 16,000 tons of steam per day, along with 100 tons of lava, at the height of its activity.

Although present-day volcanoes build up the land area immediately around them, their lava flows are small compared with some of the past. One gigantic flow produced the Columbia Plateau in northwestern United States. It is about 200,000 square miles in area and covers part of Washington, Oregon, and Idaho. The plateau is 4,000 feet deep in some places.

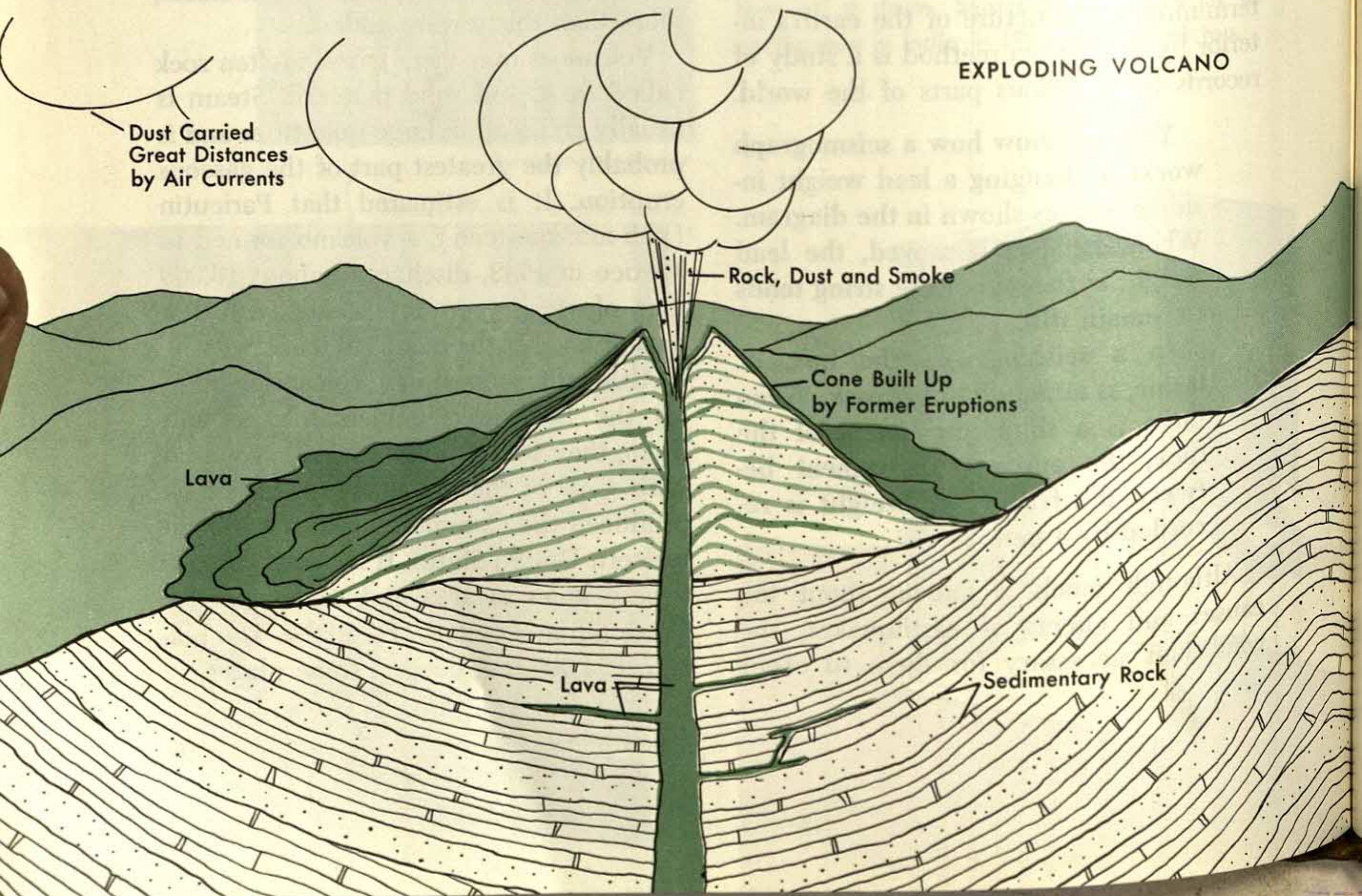
Among the gases often present in a volcanic discharge are hydrogen sulfide (H_2S), sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrogen (H_2), hydrogen fluoride (HF), and hydrogen chloride (HCl). The solid material ranges in size from dust particles so small that they stay in the air for years to masses of rock weighing tons.

The explosive force of some volcanoes is astounding. Krakatao, in the United States of Indonesia, blew a cubic mile of dust fifteen miles into the air when it erupted in 1883. The dust was carried by air currents to all parts of the world. In 1930, the volcano Stromboli, in the Aeolian Islands north of Sicily, hurled thirty-ton rocks a distance of two miles.

SUMMARY

Much of what is known about the solid earth has been learned by observing things that happen on its surface and by digging into its outer crust.

In his efforts to determine when the earth was formed and how it has changed through the ages, the scientist uses methods somewhat like that of a detective. He collects the facts at hand and uses them as clues to what happened in the past. Today it is believed that the earth is more than five billion years old. During these billions of years, its surface has changed in many ways. These changes, in turn, have affected life on different parts of the earth. Cataclysmic changes are occasion-



EXPLODING VOLCANO

Dust Carried Great Distances by Air Currents
Rock, Dust and Smoke
Cone Built Up by Former Eruptions
Lava
Lava
Sedimentary Rock

ally seen today when earthquakes or volcanic eruptions occur.

During the 50,000 years or so that man has inhabited the earth, he has explored the earth's crust and the lower parts of its atmosphere. From his exploration, he has collected much evidence about these frontiers. But the interior of the earth and below the ocean's surface are still relatively unexplored frontiers.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The slow process by which rocks are broken down is (a) sedimentation (b) erosion (c) weathering (d) creep.

2. A rock which has been changed by heat and pressure is classed as (a) sedimentary (b) metamorphic (c) igneous (d) limestone.

3. The most important action tending to build up land surface is (a) faulting (b) lava flow (c) mass wasting (d) sedimentation.

4. The most abundant element to be found in the lithosphere is (a) O_2 (b) Fe (c) Si (d) N_2.

5. In the earth's land surface, sedimentary rock amounts to (a) one-half (b) two-thirds (c) three-fourths (d) four-fifths.

6. Most fossils are found in rocks that are (a) sedimentary (b) metamorphic (c) igneous (d) granitic.

7. If the chalk board in your classroom should crack from top to bottom and slip down an inch, this would represent (a) an earthquake (b) weathering (c) a fault (d) a glacier.

8. The force that causes mass wasting on the earth is (a) water (b) wind (c) gravity (d) heat.

9. The age of the earth is being estimated with the help of (a) seismographs (b) ocean soundings (c) lead (d) clouds.

10. It takes a long time to form one inch of soil because its formation takes place mainly through the process of (a) weathering (b) metamorphic action (c) erosion (d) glaciation.

B. Applying the If-Then Method

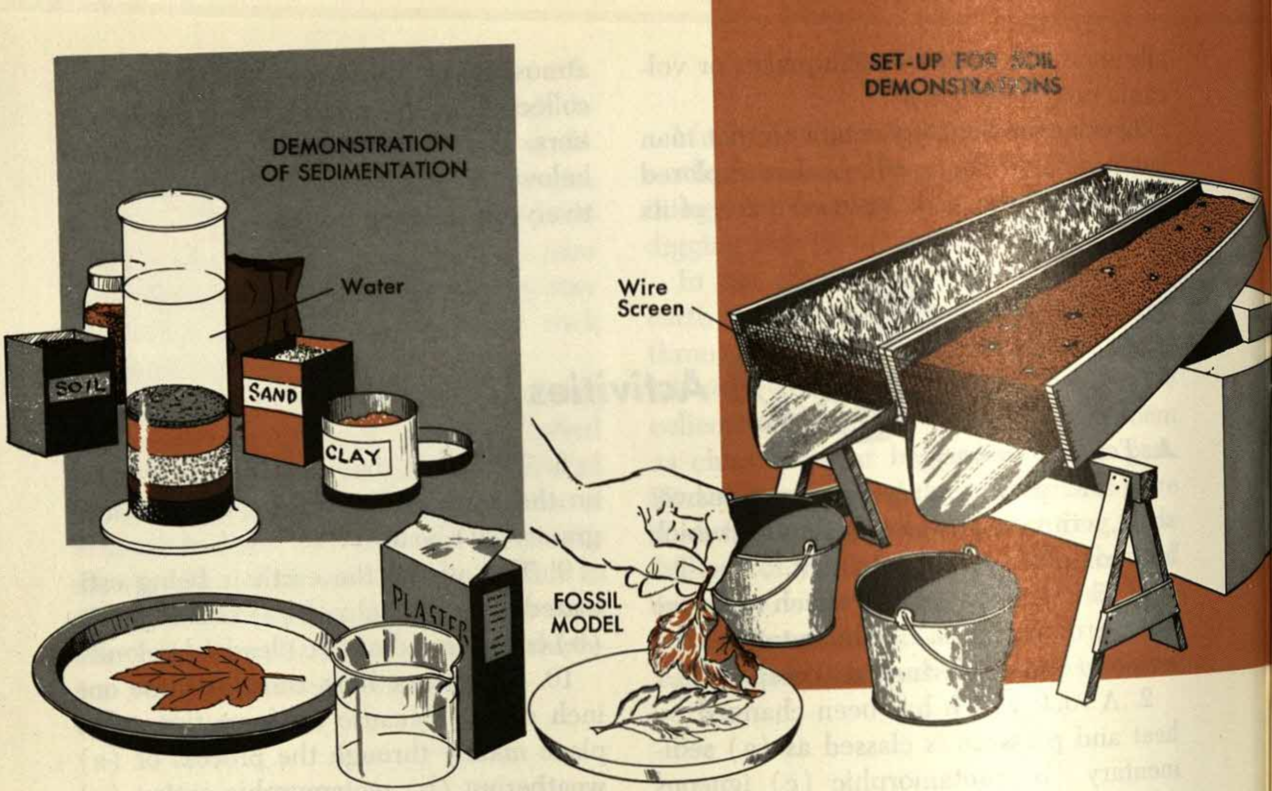
1. How could each of the following be used to make comparisons of annual rainfall in places for which there are no rainfall records: (a) tree rings (b) sedimentation where run-off water collects?

2. How is the if-then method used in locating oil and mineral deposits?

3. How is the if-then method used in determining who should go to college?

4. Have different members of your class bring in several rocks which they have found in different places. Can you answer the following questions by using the if-then method?

a. Does an examination of the rocks give you clues regarding their origin (igneous, sedimentary, metamorphic)?


DEMONSTRATION OF SEDIMENTATION
Water
SOIL
SAND
CLAY
PLASTER
FOSSIL MODEL
Wire Screen
SET-UP FOR SOIL DEMONSTRATIONS

b. Are there clues which might help you tell how the rocks came to be shaped as they are?

c. In the table of minerals on page 557, can you find clues regarding the mineral composition of the rocks?

5. What assumptions are made in using the if-then method?

C. Controlling Erosion

How does each of the following help to control soil erosion: (a) contour farming (b) strip cropping (c) contour furrows (d) cover crops (e) check dams?

D. Building Models

Often building a model will help you to understand ideas better. The following words represent ideas which you might demonstrate by building a model:

a. sedimentation
b. faulting
c. diastrophism
d. fossil
e. strip mining
f. topsoil
g. subsoil
h. lithosphere

E. Preparing Reports

Prepare reports on the subjects below:

a. Mining the earth for minerals

b. Ground water as a natural resource

c. Coal and oil reserves of the United States

d. Volcanoes of the world

F. Studying the Land

Write an autobiography of the land where you live. Write it as though the land itself were talking. Include information regarding its origin, the way it has changed, and how it has been used by people who live on it.

PROBLEM 2: WHAT ARE EARTH'S LAST FRONTIERS?

Until quite recently, exploration of the solid part of the earth has been largely limited to what can be observed on the surface. In places such as the Grand Canyon, parts of the earth's crust have been exposed to a depth of several thousand feet through erosion. The drilling of oil wells has brought up samples of materials from as deep as 25,000 feet. The action of live volcanoes has poured onto the surface evidence regarding some of the forces deep inside the earth.

MEANING OF EARTHQUAKE WAVES

Much of what man believes about the interior of the earth has been obtained by the scientific study of earthquakes. As you learned in the last problem, the seismograph records vibrations, or waves, in the

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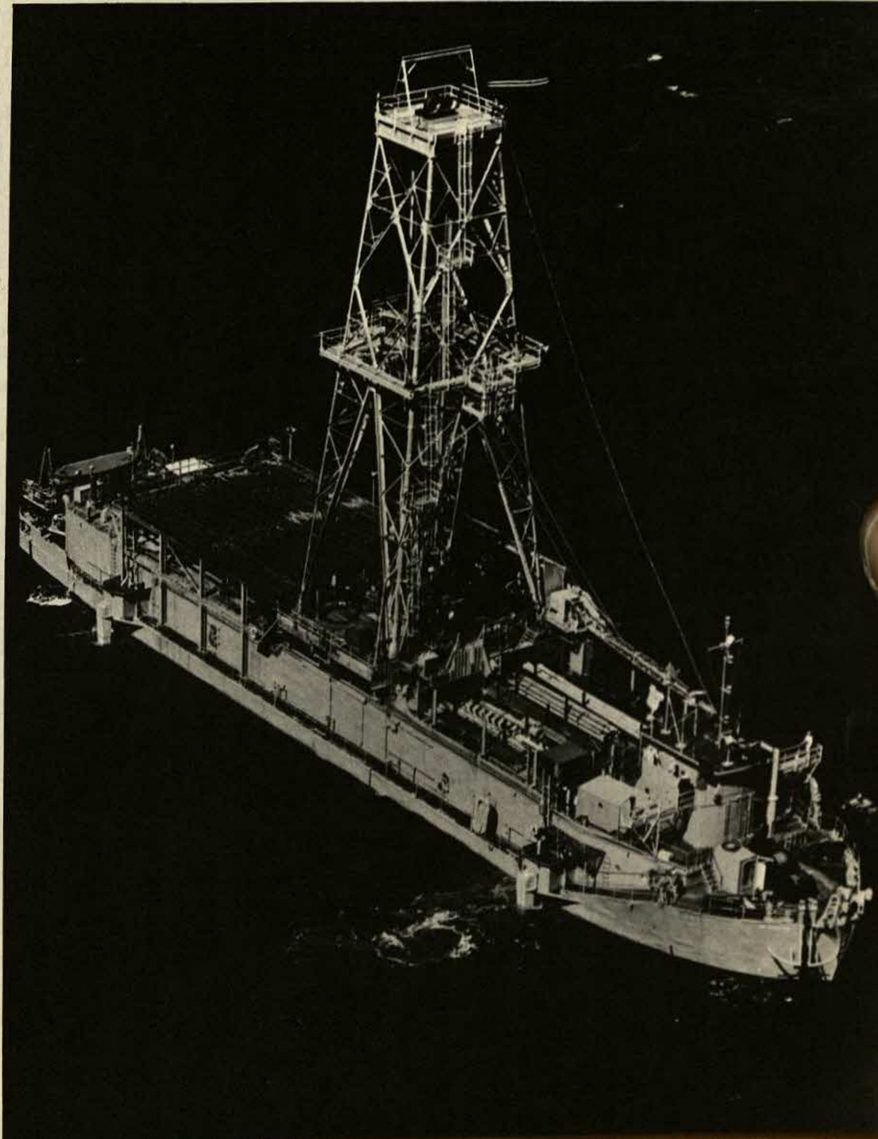


From vessel at right, Mohole was driven 560 feet through the ocean sediment down to hard rock.

earth. When an earthquake occurs, earth waves move out in all directions from its source. By measuring the strength of the waves at different places over the earth, the source of a quake can be located.

In their study of earthquakes, seismologists discovered that waves passing through the earth were leaving a shadow zone on the opposite side. That is, few waves, for some reason or other, were getting through. Most of them were being deflected. From this evidence, scientists decided that there must be a dense core at the center of the earth. This core either blocked, or deflected, the waves. They reasoned, further, that the core would be under such great pressure, and subject to such great heat, that it could not be a solid, but must be a liquid. If it were a liquid, then it had to be denser than any liquid man could possibly imagine. Man's ideas about such things as density and the nature of liquids are limited to his experience on the surface of the earth. Things must be quite different at the center of the earth.

Temperature of the Earth's Interior

In the world's deepest gold mine in India, a half-million-dollar air-conditioning system had to be installed to keep the miners from being roasted. At the bottom of its two-mile shaft, the temperature is 150°F.

At the bottom of the world's deepest oil well in Texas, nearly five miles down, the temperature is almost twice that of boiling water.

Scientists have calculated that, for every sixty feet of depth in a mine or well, the temperature increases about 1°F. If this rate of temperature increase continued, at thirty miles down a temperature of 2,500°F would be reached. Many measurements of lava in volcanoes indicate that this estimated figure is fairly accurate. Temperatures at the center of the earth must be extremely high. The pressure there must be almost four million times greater than atmospheric pressure at the surface of the earth.

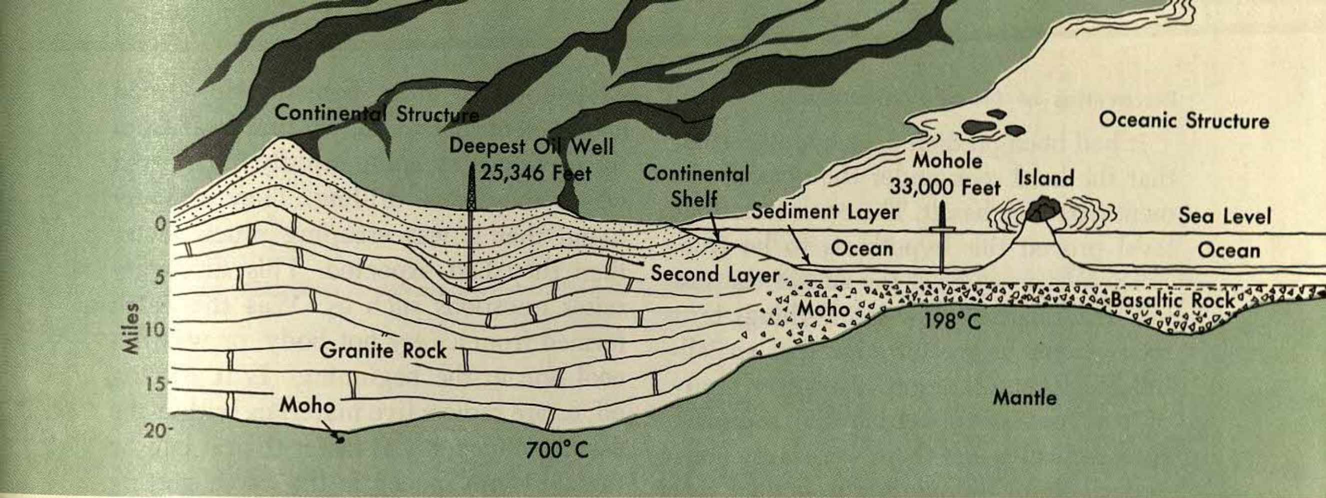
EARTH'S LAYERS

From a great many studies made of the time and direction taken by earthquake waves as they pass through the earth, the depth of the various layers, as shown on page 287, has been determined. The core is estimated to be 4,400 miles in diameter. It is surrounded by solid rock called the ***mantle.*** The mantle, which is about 1,700 miles thick, lies beneath the earth's outer crust. The thickness of the crust varies from ten to twenty-five miles.

Moho

A Jugoslav seismologist by the name of Andrija Mohorovičíc (ahn-DREE-jah moh-hoh-roh-VEE-chic) discovered the earth's mantle. He believed that the earth had a distinct crust, clearly separated from the mantle. The boundary where the crust and mantle are separated is called the ***Mohorovičíc Discontinuity,*** or ***Moho.*** The word discontinuity means an abrupt change of properties between two kinds of material.

The description of the earth's crust, (see page 569), should be thought of only as a hypothesis. The hypothesis is supported by good evidence. Furthermore,



Profile of the ocean floor in the vicinity of the Project Mohole is diagrammed above.

it is generally accepted by seismologists. But no one knows for certain because scientists have had no direct evidence. To prove the hypothesis that there is a Mohorovičíc Discontinuity would require additional evidence. And this is just what a group of scientists have set out to get. The work these scientists are doing is called ***Project Mohole.*** The goal is to drill a hole completely through the earth's crust into the mantle. Can you see why the project has been called "Mohole"?

Drilling a Mohole

If you were going to drill a hole through the earth's crust, where would you go to do it? The Mohole scientists decided that it should be drilled at a place where the crust is thinnest, and this is at the bottom of the ocean. There are some thin spots in the ocean where the crust is only two, or three, miles thick. All the drillers had to do was to get through this thin layer. However, it was necessary to drill where the water is about two miles deep. The scientists called for help from oil companies who had long experience in drilling oil wells under water. The ship shown on page 567, used in the first drillings, was originally built for drilling oil wells at sea.

As you learned in the last problem, oil wells are drilled through long strings of pipe. A string of pipes two miles long is somewhat like a piece of baling wire 400 feet long. You can see what a problem it would be to keep the pipe from breaking when the ship drifted. Again the scientists needed help. This time they called upon engineers, who worked out a plan whereby the ship automatically could be held in a position directly over the hole two miles beneath it.

As this is being written, Mohole engineers have succeeded in drilling a test hole through 560 feet of ocean sediment into hard rock. As the drill cut through the sediment, cores of materials were cut out. These cores, removed by tools lowered through the pipe, were carefully examined by the scientists. Although they have not reached Moho as yet, they have made a number of interesting discoveries.

Discoveries of Mohole Scientists

It had been predicted, or hypothesized, that the hard rock under the ocean sediment would be basalt. The cores from that level proved this hypothesis to be true.

The ocean water at the site of the test hole has relatively few living things in it today. Some have referred to it as an "all-but-lifeless ocean desert." However, study of the fossil record from the sediment cores indicates that there were large numbers of living things in the waters that produced this sediment twenty-five million years ago. Here is an example of how one discovery raises other questions. Why does this part of the ocean not produce as many living things today as it did twenty-five million years ago? What has happened here?

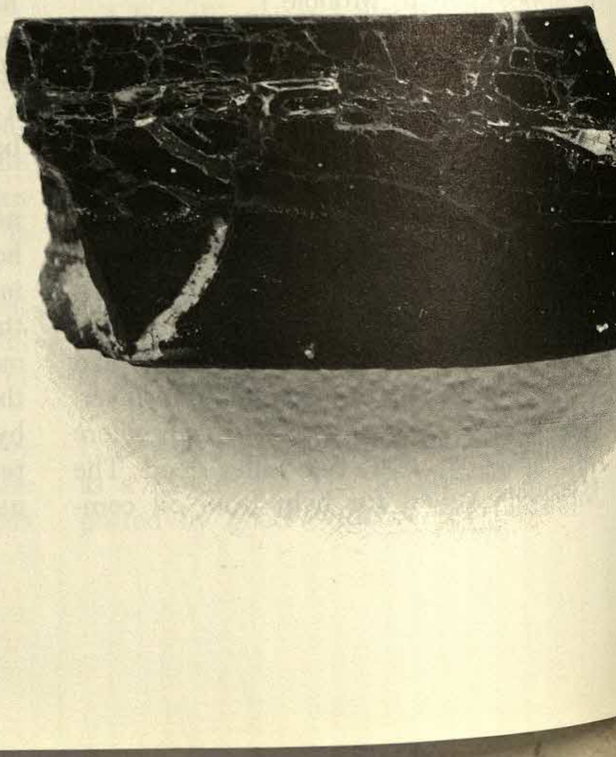
Instruments for recording temperatures were sent down through the drilling pipe. For the first time, temperature readings were obtained from beneath the ocean floor. Scientists had known that heat from the earth was escaping rapidly in the area where they were drilling. They actually found that it was escaping much faster than they had expected. This discovery raises questions such as: Was the earth formed from a very hot body, or was it a cool one in the beginning? Is it cooling off, or are radioactive materials within the earth producing heat faster than it can be radiated into space? Is the earth getting warmer or cooler?

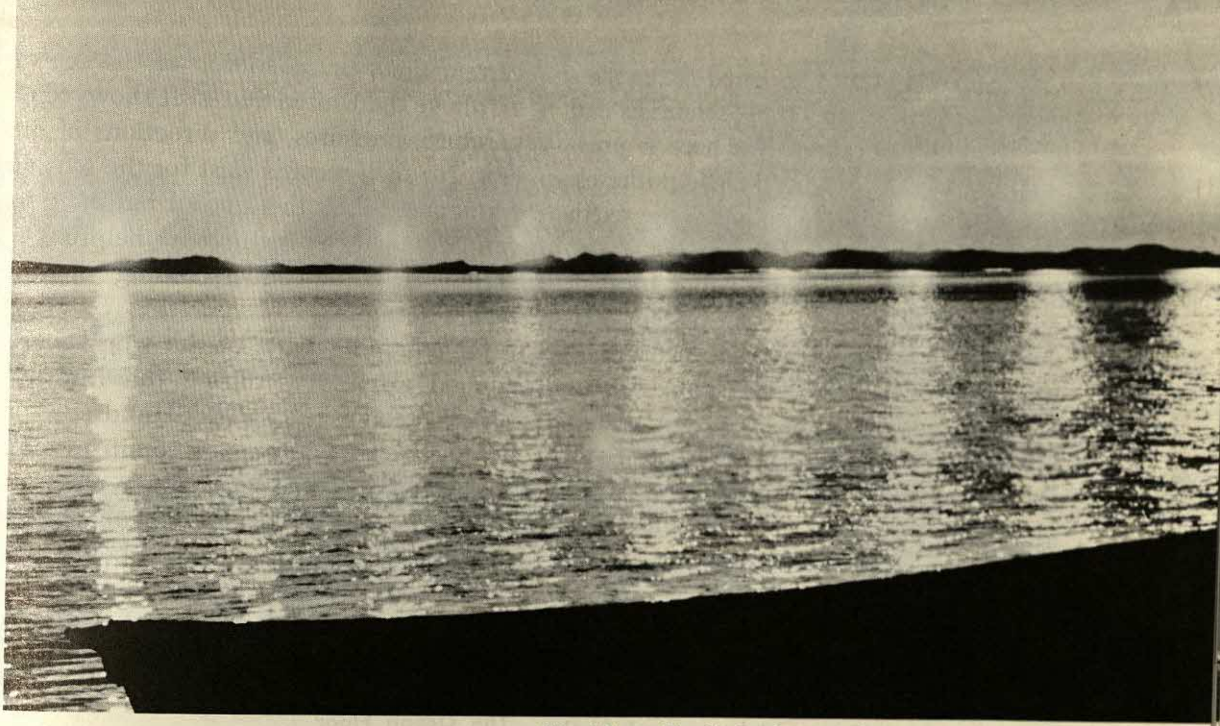
The interior of the earth is still an unexplored frontier. The discoveries that have been made through the drilling of one little hole 560 feet deep excites curiosity and imagination. These cause man to continue to push into new frontiers for knowledge. By the time you read this, many more discoveries may have been made by scientists.

Diamond-studded drill, left, was used to drill Mohole. At right is one of the cores brought up.

National Science Foundation

National Science Foundation—U.S.G.S.





Div. of Ec. and Tourist Development—State of Alaska—Juneau

The midnight sun is reflected in the Arctic Ocean, earth's northernmost body of water.

THE EARTH'S OCEANS

Look at an earth globe. As you know, those parts colored blue are oceans. Oceans cover seventy-one percent of the earth's surface, or 139 million square miles. On an average, they are two and one-third miles deep. Although man has sailed the seas for many centuries, his knowledge of them is very limited. In fact, he knows less about many parts of the ocean than he does about the surface of the moon. The science of oceans is called ***oceanography.*** It is a very young science, which got underway only 100 years ago, but it is growing rapidly. It is dependent upon many other fields of science, such as geology, chemistry, physics, and even biology.

It is known that oceans have played a very important part in the lives of all people. Scientists believe that life originated in the oceans. They have always been a vast storehouse of food for man. It has been discovered that oceans may be an important source of minerals, too. They furnish most of the water vapor in the earth's atmosphere, which, in turn, supplies life-giving rain. They also regulate land temperatures in many parts of the earth. It is quite proper, scientifically, to say that without the ocean, living things would not have developed as they have developed on the earth.

Origin of Ocean Waters

From where did the ocean waters come? Here is another question that deals with something that happened in the irrecoverable past. At this time, scientists can only hypothesize about it. There is presently no way of proving their hypotheses.

According to one hypothesis, the earth began as a body of extremely hot gases. As it began to cool, water vapor formed. As it cooled further, water vapor condensed and rains fell. It was a very long time before the earth had cooled to the state where liquid water could collect upon its surface. Finally, the surface of the earth cooled to its present state and oceans were formed.

According to another hypothesis, the earth formed from a collection of cold, dust-like materials in space. As more and more material was added, great pressure and heat developed inside. This brought on volcanic action, which spewed forth many gases, including steam. The steam condensed to form most of the water in the oceans.

Regardless of how the earth was formed, one highly respected scientist believes that not more than ten percent of the ocean water was formed by the first rains. He believes that at least ninety percent of the ocean water was formed from volcanic action. He further believes that the atmosphere, oceans, and rocks of the crust have all been produced by volcanic activity. The Mohole Project, described earlier, may supply evidence that will make it possible to test these hypotheses regarding the origin of the earth and its ocean waters.

Exploration of the Oceans

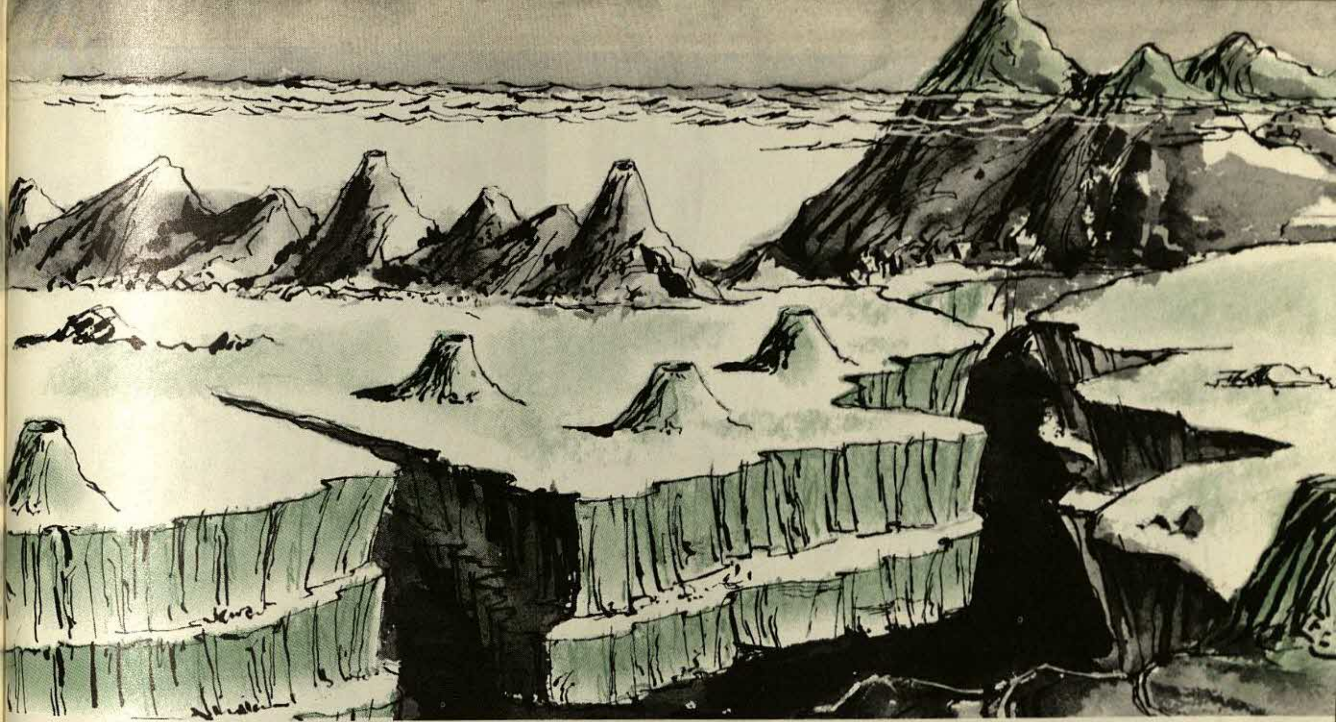
Examine again the weather map on page 365. The map actually shows, as of a certain time, the condition of the sea of air above the United States. It shows temperature, pressures, and directions of air flow. No such records exist for the seas of water. Yet this is the kind of information which would be extremely helpful in getting a better understanding of the earth's oceans.

Oceans in all parts of the world were studied extensively during the International Geophysical Year. Hundreds of oceanographers from many countries took part. They went to sea in their research ships for eighteen months to collect evidence that would give man a better understanding of such things as the floor of the ocean and the circulation of the waters of the ocean.

The Ocean Floor

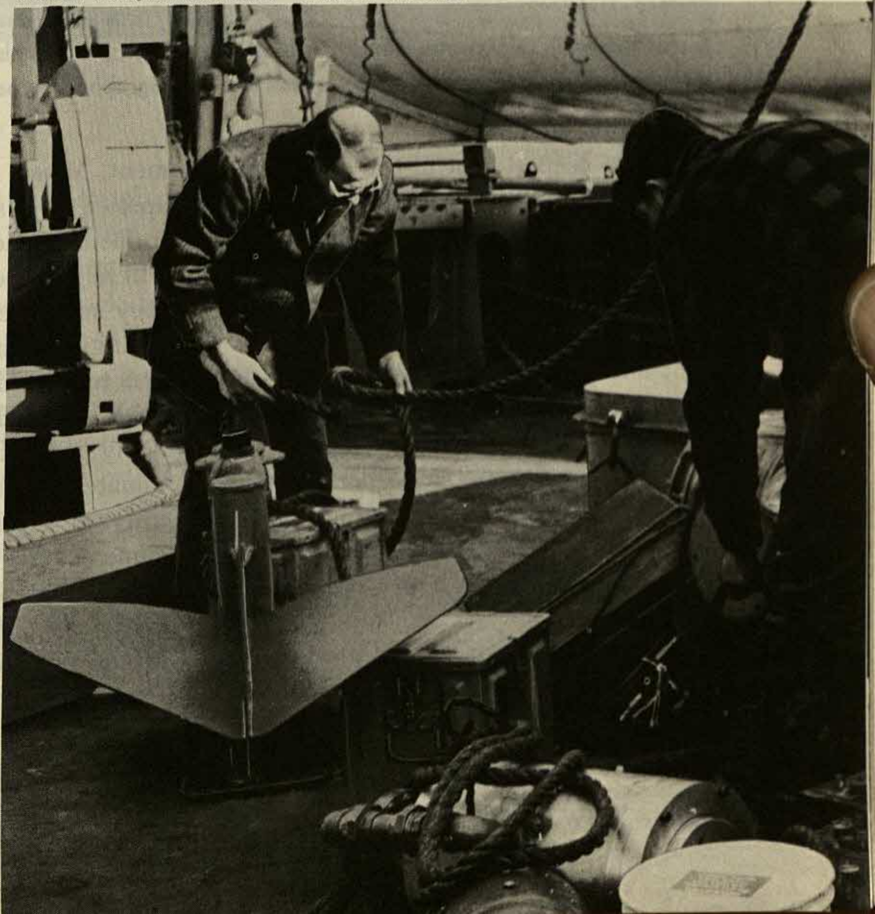
A number of different methods are used in collecting evidence about the ocean floor. Instruments similar to sonar, described on page 127, are used to map the ocean floor. These instruments send sound impulses to the bottom of the ocean, from which they are reflected back as echoes. The time it takes for the echoes to return from the ocean floor indicates to the observer the distance to the bottom. Recording equipment plots a profile of the ocean floor like the one shown on page 569. This is how mapping of the ocean floor got under way.

Towering mountain ranges and deep trenches have been found on the ocean floor. The mountains are higher, and the trenches are deeper, than any mountains or canyons on the surface of the earth. The Marianas Trench near the Marianas Islands in the Pacific Ocean has been found

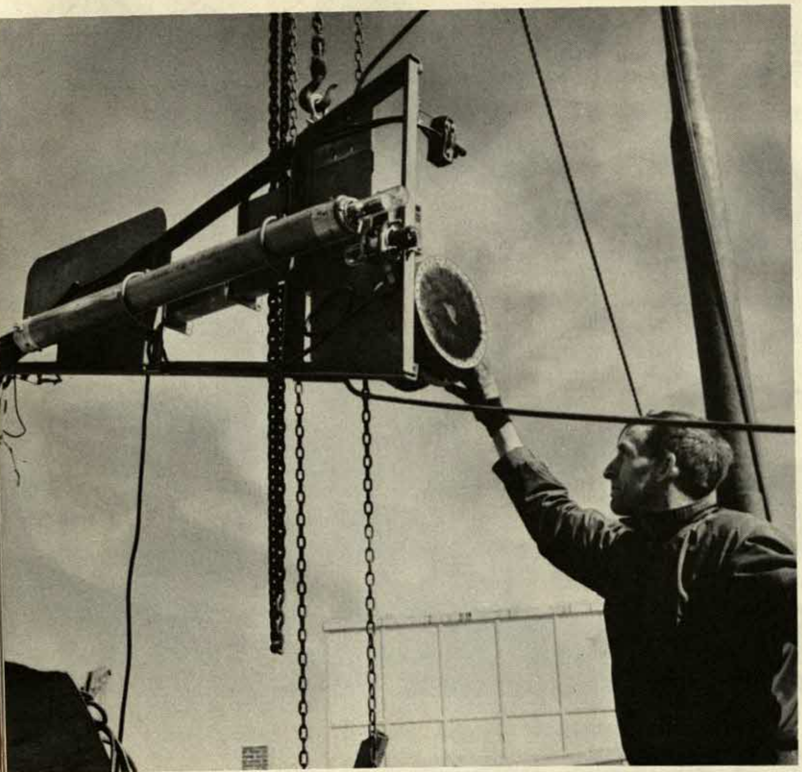


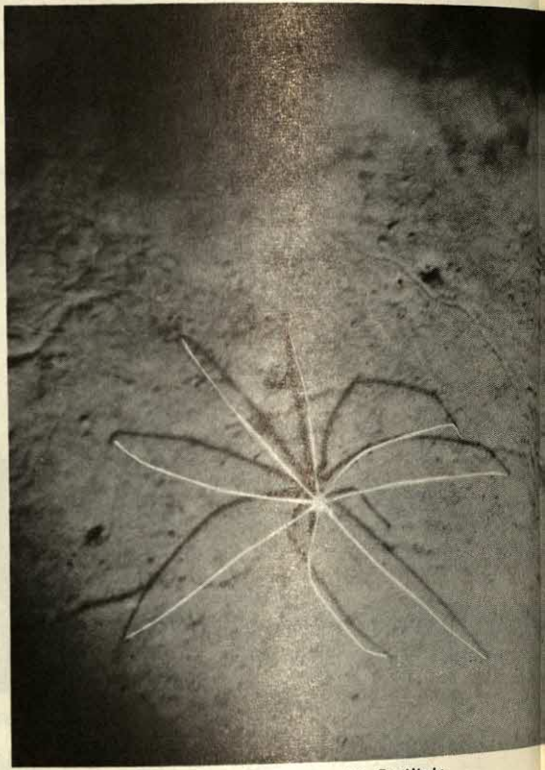
Seamounts, guyots, and abyssals are shown in the diagram of the ocean floor, above.

Lamont Geological Observatory—Columbia University



Seismic profiler in foreground is used to generate sound waves under water. The time sounds take to return as echoes is used to chart profile of ocean floor.





Two photographs by Woods Hole Oceanographic Institute

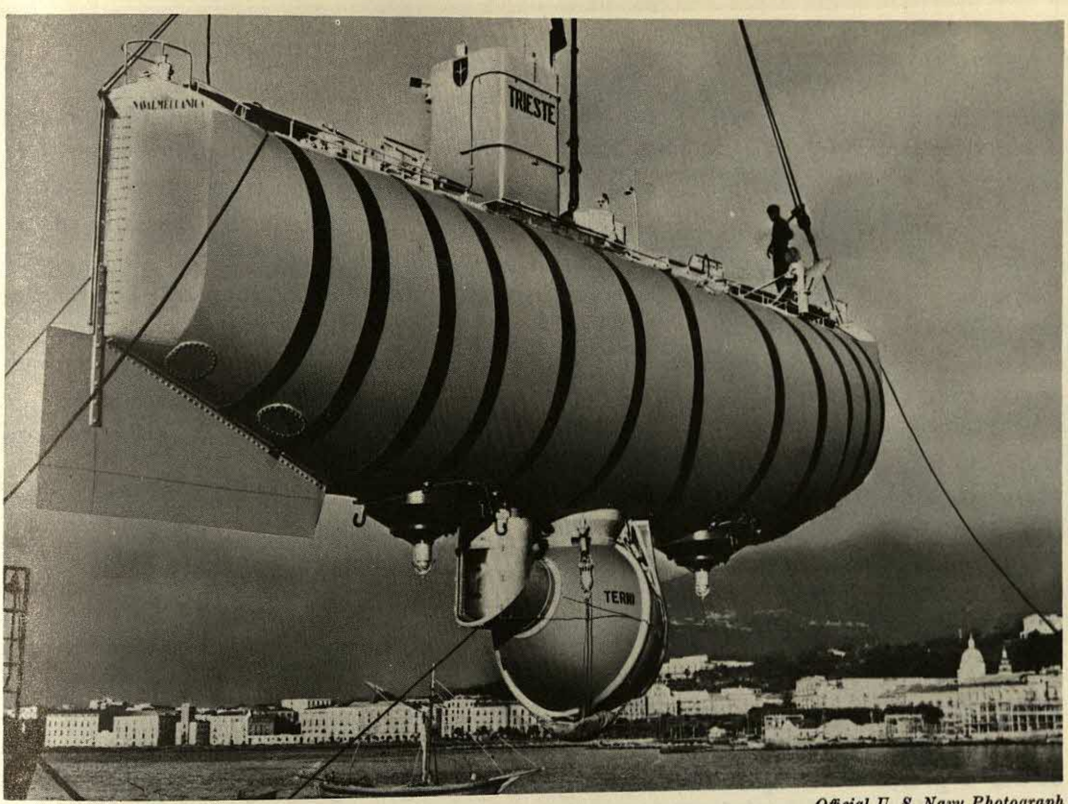
Sound-triggered underwater camera is used to photograph animals that swim into its range when it is lowered into ocean. Spider-like animal was photographed on ocean floor by such a camera.

to be the deepest spot in the ocean—36,056 feet below the surface. It is so deep that seven Grand Canyons could be piled on top of each other in it. Its length is equal to the distance between Kansas City and New York City.

Seamounts, such as those shown in the diagram on page 573, are mountains formed by volcanic action. ***Guyots*** (GEE-ohz) are the flat-topped undersea mountains. Broad ridges of mountains stretch the length of an ocean. ***Abyssal*** (uh-BIS-'l) plains as smooth as a football field have been found.

Deep-coring devices have been used to bring up sixty-foot cores of ocean sediment. When these cores have been examined by scientists who have been trained to read the stories they tell, much will be learned about the seas and the life they supported.

Engineers have built complicated cameras to extend the oceanographer's vision to the ocean floor. Because it is so dark in many parts of the ocean, the camera illuminates the area to which it has been lowered to take a picture. Deep-water cameras have brought back pictures from more than four miles below the surface of the sea. The spider-like animal shown on this page was photographed by a deep-sea camera.



Official U. S. Navy Photograph

Bathyscaphe *Trieste* is shown being lifted out of water for its return to the United States.

Bathyscaphes

Oceanographers have not been satisfied to get their evidence about the bottom of the ocean indirectly from cameras and other devices. They wanted a look for themselves.

Bathyscaphes (BATH-ih-skayfs), such as the one shown on this page, have made it possible for scientists to descend to the ocean floor and explore it. The word "bathyscaphe" is a combination of two Greek words meaning *depth ship.*

One of the problems in building such a ship is to make it strong enough to withstand the tremendous pressures on the ocean floor. Water pressure in the sea increases .44 pounds per square inch for every foot of depth. At the bottom of the Marianas Trench, the pressure is more than one-and-a-half million pounds per square inch.

The late Auguste Piccard, famous Swiss physicist, was a pioneer developer of both stratosphere balloons and bathyscaphes. One of his latest bathyscaphes, the ***Trieste,*** shown on this page, was purchased by the United States Navy. It was used by his son, Jacques Piccard, and Lieut. Donald Walsh in the famous descent which they made to the bottom of the Marianas Trench on January 23, 1960. Accounts of this exciting adventure referred to it as one that had taken man into the last unexplored frontier on earth.

Ocean Temperatures

As you learned in Unit 7, circulation of the atmosphere is brought about by the exchange of cold and warm air masses. The same principle holds for the circulation of water masses. Thus, by measuring ocean temperatures at different depths and at many places, evidence can be obtained that helps to describe ocean circulation.

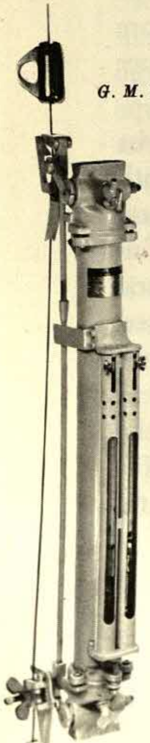
A special instrument called the ***Nansen bottle*** has been developed to measure the temperature of water at different depths. The bottles trap the ocean water, and thermometers attached to the bottles measure the different temperatures. When a ship pulling strings of these bottles passes along a given track, the evidence collected by them can be used to construct a profile of temperature layering in water, shown below, left. From such charts, oceanographers can obtain clues to ocean circulation and currents.

THE FOOD PROBLEM

There are two important reasons for man's desire to find out more about the sea. The first reason is to satisfy his curiosity. As you will recall, this kind of exploration has been referred to as basic science. In this way, man satisfies his desire to understand better the world in which he lives. As each new bit of knowledge is discovered, he fits it into what he already knows and thus enlarges his understanding.

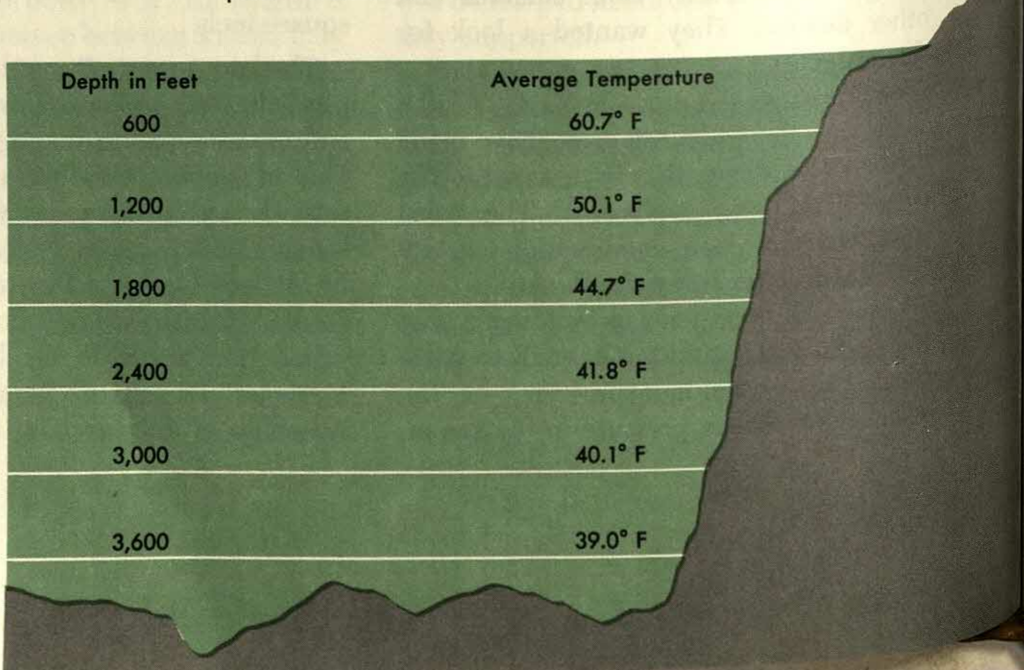
The second reason for man's curiosity about the sea is based on his desire to find ways in which the sea can be used to solve some practical problems. One of the very real practical problems which faces man today is a shortage of the right kind of food. It has been reported that more than three-fourths of the people of the world are not getting enough of the right kind of food. Protein is the kind most needed.

The problem becomes more serious each day. It has been estimated that the



G. M. Mfg. Co.

Nansen bottle at left is used to measure temperature of ocean water at different depths.



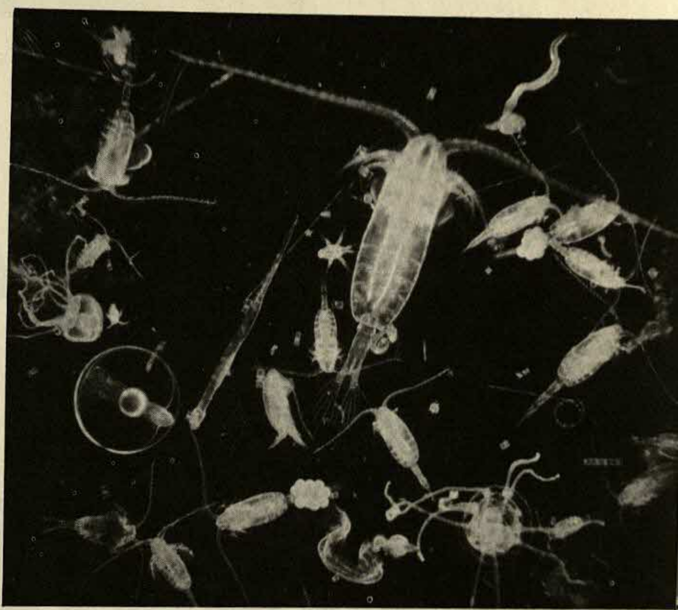
Depth in Feet	Average Temperature
600	60.7° F
1,200	50.1° F
1,800	44.7° F
2,400	41.8° F
3,000	40.1° F
3,600	39.0° F

population of the earth is increasing at the rate of more than 100,000 a day. Each year there are about 60,000,000 more people to be fed than the year before. It is difficult for those who live in the United States to realize how serious this problem is becoming. Most Americans are pretty well fed. In fact, this country's farmers produce more of such crops as wheat and corn than can be used. Much of this surplus is shipped to other countries. Even then, there is an especial lack of protein foods in many countries.

As you will recall, the body uses protein to build tissue and to make enzymes, hormones, and antibodies. Without enough protein, bodies become weak and unable to fight diseases. Because the animal life of the sea is rich in protein, it is possible that better use could be made of it. This is a practical reason for finding out more about the sea.

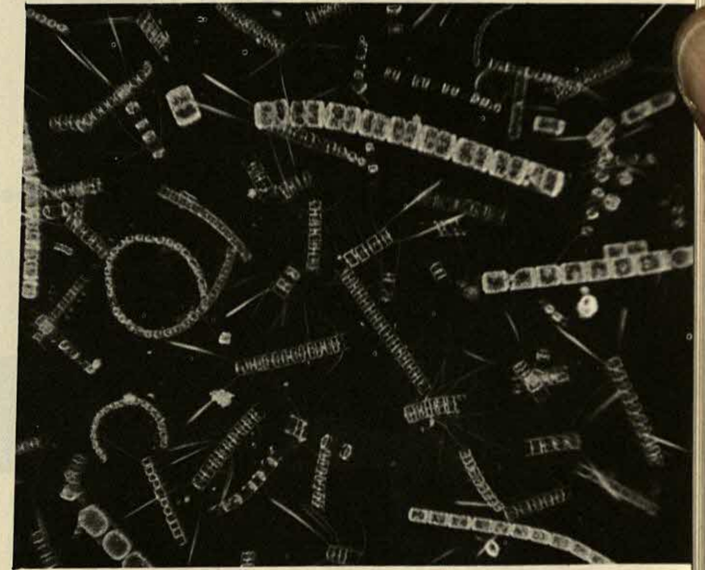
Ocean Food-Producers

All living things depend upon green plants for food. Somewhere in the food chain of sea animals there must be green plants. The green plants of the sea are not so conspicuous as many of those on land. It is difficult to see many of them without a microscope. They are mostly algae, and are called ***phytoplankton.*** "Phyto" means plant and "plankton" is a word applied to those organisms which are carried about by water. Some examples of phytoplankton are shown on this page. There are also ***zooplankton*** shown on this page. These are the many kinds of small animal organisms which live upon the phytoplankton. Together they are called the plankton of the sea. All animals



Photos by Douglas P. Wilson

Swarming microscopic life of sea is shown in these two photographs. At top is living marine zooplankton. At bottom is phytoplankton.



of the sea are dependent, either directly or indirectly, upon plankton for food.

Because phytoplankton must have light, the plankton of the sea grows near the surface of the water. None is found deeper than 300 feet. You would expect, therefore, to find much of the animal life of the sea above 300 feet. This is true, but there is also a great variety of animals which make their homes near the bottom. They feed upon dead plants and animals which rain down from the upper levels of the ocean. As a source of food for animals, the larger algae plants, called seaweed, which are shown on page 404, are of little importance as compared with plankton.

Oysters, Fish, and Reptiles

More than ninety percent of the total mass of animal life in the sea is made up of ***invertebrates.*** Many of these, such as sponges, jellyfish, and sea cucumbers, have little food value for man. But others, such as oysters, clams, lobsters, shrimp, and crabs are quite important. Oysters are one of our best sources of animal protein.

Fish have always been man's most important source of seafood. Although more than 25,000 different kinds of fish have been identified, not more than two percent are used very much. Most of them live on continental shelves in depths of less than 600 feet.

The reptiles include sea snakes and sea turtles. There are at least thirty different kinds of sea snakes, which live close to shore. While most sea snakes bear their young alive, some go up onto the land to lay their eggs.

Sea snakes live on fish, especially eels. Some grow as long as nine feet, although some are only four feet long. Sea snakes are caught and used as food in some parts of Asia.

Sea turtles live in warm waters near the land, although some may go quite a distance out to sea. But all turtles go ashore during the breeding season to lay their eggs. The destruction of many of their breeding grounds has greatly reduced the number of sea turtles in places where they were once very plentiful. Although sea turtles could never become an important source of food, yields could probably be improved by proper conservation.

Mammals

Whales and other sea mammals such as dolphins, seals, walruses, and sea otters are the most valuable of all the sea animals. Their use is limited, however, by the fact that their number is so small and their reproductive rate is so low compared with fish. For these reasons, their ranks can be dangerously reduced by uncontrolled hunting of them.

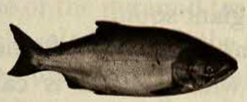
Two types of whales have been hunted extensively—the ***baleen*** (buh-LEEN) whale and the sperm whale. Eighty percent of the baleen whales caught in 1955–1956 were captured around Antarctica.

The baleen whale has no teeth. Instead, it has a series of 300 or more horny plates arranged on either side of its palate. The plates, made of a substance called baleen, range in size from two feet to twenty-five feet in the larger whales. The plates are commonly called whalebone. The inner margin of the plates is fringed. When water passes over them, the plates serve as a sieve to strain out plankton and very small fish.

LIFE IN THE SEA

Walrus

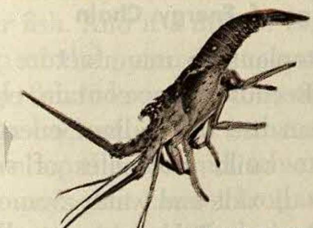
American Museum of Natural History



Salmon

AMNH

Spiny Oyster



Walter Dawn

Spiny Lobster

Sea Horse

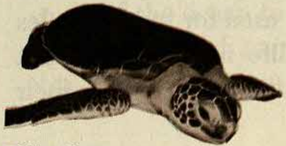
American Museum of Natural History

Walter Dawn

Spider Crab

American Museum of Natural History

Hard-shelled Clams



Walter Dawn

Green Turtle

The smallest type of baleen whale is only twenty feet long. The largest, the blue whale, not only grows big, but fast. At birth, the blue whale is about twenty-four feet long. In about three years, it is seventy-five feet long, and at full growth it is more than a hundred feet long and weighs as much as 125 tons. The whale is truly a remarkable machine to be able to convert plankton into such an enormous amount of whale meat in such a short period of time.

Another whale valuable to man is the sperm whale. It is a toothed whale that is able to go down into the sea almost half a mile. It lives on giant squid.

One kind of clear, colorless oil found in a cavity of this whale's head is called ***spermaceti*** (sper-muh-SET-ee). It changes to a solid white wax when exposed to the air. This oil is used in the manufacture of many products, including cosmetics and candles.

Before 1850, sperm whales were extremely important, as oil obtained from them was used for illuminating purposes. But by the middle of the nineteenth century, mineral oil was replacing whale oil for lighting purposes. By that time, too, sperm whales were so greatly reduced in number that the industry fell off. In the last twenty years, however, there has been a revival of sperm whaling. In 1955–56, the 18,000 sperm whales caught represented about thirty percent of the total whale catch.

Seals are another important sea mammal. Although caught primarily for their hides, some are also used for food. Whales spend their entire life in the water, but seals must go onto land or ice to bear their young. It is at these times that most of the seals are caught. Seals feed upon fish, shellfish, and sea birds. Unregulated hunting of seals has greatly reduced the population in many places. Today seal hunting is regulated, and there are more seals.

Walruses are hunted for their meat, oil, hides, and ivory. Their number also was greatly reduced until the hunting of them became regulated.

FOOD CHAINS AND PYRAMIDS

In an earlier unit of this book, interdependence of living things was discussed. In this system, one organism depends upon another for shelter, food, or both. The food dependence might be called an energy chain, because each organism depends upon the one it eats for energy. There is another important idea in this process. Life in the sea can be used to develop it.

Workings of Energy Chain

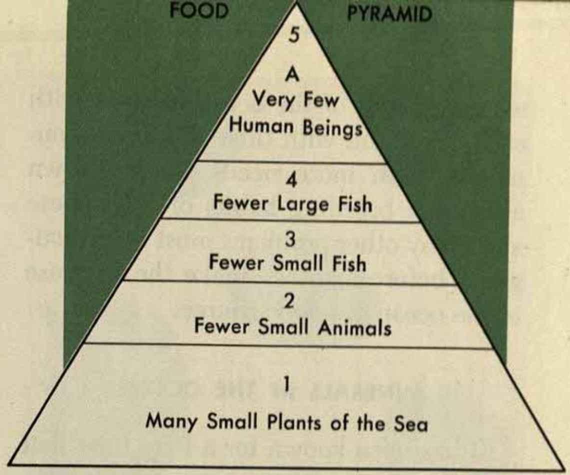
Phytoplankton manufacture their own food. Because they contain chlorophyll, they can use the radiant energy of sunlight to build molecules of sugar from carbon dioxide and water. Some of the energy from sunlight is chemically trapped in the sugar molecule. When green plants make starch, protein, and fats from sugar and other materials, much of the original energy remains locked up in these sugar molecules.

When animals such as zooplankton eat phytoplankton, they use this energy in two ways. One is for the purpose of carrying on their life activities; the other is for the purpose of building up their bodies.

The molecules of protein and fat that go into their bodies contain only a part of the energy that was in the food that they used. When small fish eat the zooplankton, a part of the energy they get from this food goes to run their bodies and the remainder is trapped in the materials that make up their bodies. When larger fish eat smaller fish, the same thing happens. The materials making up their bodies contain less trapped energy than they obtained from the food they ate. At each link along the food chain, some of the original energy is lost. Less and less of it becomes available to animals farther along the chain. The idea can be shown by the ***food pyramid*** shown in column 2.

In the beginning, or at the bottom of the pyramid, are the phytoplankton of the sea. It takes many phytoplankton to supply a few zooplankton with the energy they need. At the next step up, it takes many zooplankton to support a few small fish. It takes many small fish to support a few larger fish. And if a man or seal were at the top of the pyramid, it would take many large fish to keep one of them going.

The idea back of all this is that at each animal level up the pyramid, some energy is used in ways that cannot be passed on to the next animal level. Similarly, there is less protein available at each succeeding level. That is why this setup is called the food pyramid. The farther down you go in the food pyramid, the larger the number of organisms required to support those above them.



Harvests of the Sea

Because man's food problem is primarily one of getting energy, the longer he waits in the food pyramid to take his food, the less energy is available. The idea of man going directly to plankton at the base of the pyramid for this food has been explored. After all, the baleen whale does very well at this level. But the baleen whale is naturally adapted to collecting and using this kind of food. Could man get all the material he needs from plankton? There is some evidence that he could. Could he harvest the plankton in sufficient amounts to make the effort worthwhile?

It has been estimated that fishermen can catch fifty-nine tons of herring in 100 hours. To harvest this much plankton, it would be necessary to strain fifty-seven million tons of sea water. Dr. Lionel Walford, an American fisheries biologist, has said, "It looks as if plankton harvesting should be left to the sea creatures best fitted to do it, namely, whales, herrings, and the like."

In order to make better use of the food animals of the sea, Dr. Walford believes that man needs to find out much more about them. There must be a systematic study of the ocean to identify more of the various kinds of animals that inhabit it. Not much is known about the ways in which animals of the ocean interact with each other and with their ocean environment. Much more needs to be known about the breeding habits of fish. These and many other problems must be investigated before man can make the best use of the ocean as a food source.

MINERALS IN THE OCEAN

It has been known for a long time that the ocean is a vast storehouse of minerals. Furthermore, the sources of many important minerals in the earth's crust are rapidly being exhausted. For this reason, there is great interest in recovering minerals from the ocean. But what is the evidence regarding minerals in the ocean?

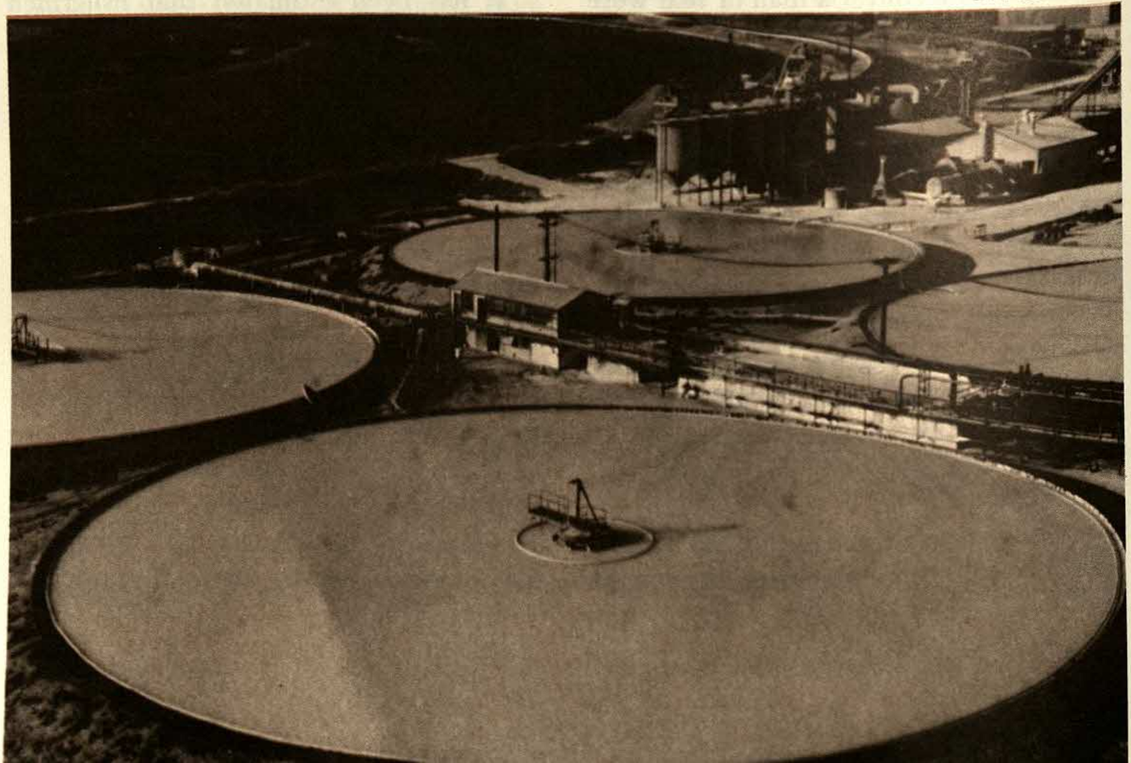
Through the ages, minerals have been dissolved from the soil and rock by water on its way to the sea. It is estimated that 7,000 cubic miles of water run off the land into the sea each year. This run-off carries, along with other minerals, 160 million tons of sodium chloride. Today, in every cubic mile of ocean water, there are 166 million tons of dissolved salts. Over four-fifths of them are sodium chloride. However, there are twenty-six million tons of magnesium, four million tons of potassium sulfate, and relatively small amounts of many other elements such as copper, tin, iodine, and zinc.

Mineral Extraction From Sea Water

Although the ocean holds an abundance of minerals, it is often not practical to extract them from sea water. For example, there is supposed to be twenty-five tons of gold in a cubic mile of sea water. However, the processes that have been developed for extracting it cost more to operate than the gold is worth. Today, man gets all his magnesium and eighty

Tanks of sea water at chemical plant, below, yield magnesium hydroxide after treatment by lime.

Dow Chemical Co.



percent of his bromine from sea water. Other minerals now produced commercially from sea water consist of mixtures of potassium and sodium compounds, magnesium and calcium compounds, and sodium chloride.

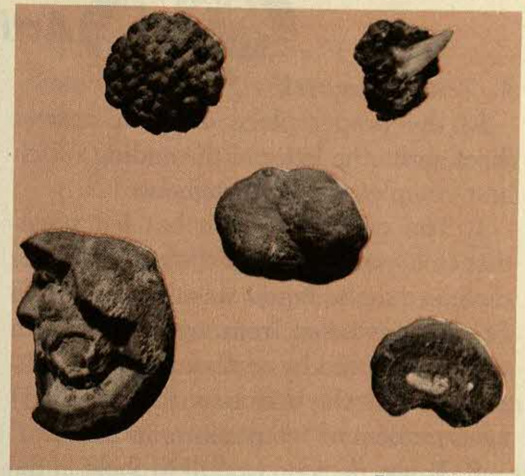
Two methods have been used to remove minerals from sea water. One is by evaporation of water. The evaporation method has been found impractical because of the large amounts of water which have to be processed. A second method whereby the mineral salts are changed chemically so that they separate from the water has been found practical for the extraction of magnesium and bromine.

Mining the Ocean Floor

Oceanographers have known, for some time, that there were valuable metal deposits lying around on the ocean floor. Nodules, or lumps of material containing important metals such as manganese, cobalt, nickel, and copper, have been found in many places. The nodules generally run about twenty percent manganese, fifteen percent iron, and five-tenths percent each of nickel, cobalt, and copper. The nodules, ranging in size from one half to ten inches in diameter, are potato-shaped.

It has been estimated that there are fourteen million square miles of ocean floor where there are sufficient nodules to make mining worthwhile. The problem of how to get them to the surface is being worked on by engineers.

It has been recommended by a national committee of scientists that more attention be given to exploring the possibilities of making better use of mineral deposits on the ocean floor.



Roman Vishniac

Lumps of metal were found on ocean floor.

SUMMARY

A study of the behavior of earth waves has been used in arriving at man's ideas about the interior of the earth. Evidence to be obtained from Project Mohole will be used to check present ideas about the origin of the earth, its internal temperature, and the characteristics of its materials at different depths through Moho.

The important role of the ocean in sustaining life on earth has been recognized for a long time. What it is like beneath the surface is a mystery that oceanographers are working hard to solve. During the International Geophysical Year, oceanographers in all parts of the world collected a great deal of evidence about the ocean's floor and the circulation of sea water.

Although the ocean is a vast storehouse of food and mineral resources, much more evidence is needed before maximum use can be made of it. The ocean is a promising field for continued exploration.

Activities

A. Testing Yourself

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. The evidence which has led scientists to hypothesize that the center of the earth is a dense liquid was obtained from (a) borings taken from mines (b) earth waves produced by earthquakes (c) sedimentation at the bottom of the ocean (d) measurement of temperature in mines.

2. It was decided to drill Mohole in the ocean because (a) it is easier to drill through water (b) old oil wells could be used (c) the crust is thinnest at the bottom of the ocean (d) they wanted to learn more about ocean sediments.

3. Cores taken from the first Mohole test drilling proved that (a) the rock under the ocean sediment is basalt (b) the interior of the earth is a dense liquid (c) water in the ocean is getting cooler (d) there were no living things in the ocean twenty-five million years ago.

4. According to the cold-dust hypothesis regarding the origin of the earth, the earth became hot as a result of (a) collision with other planets (b) being a part of the sun (c) its rotation (d) great internal pressures.

5. It is believed by some scientists that volcanic action may have (a) produced most of the water in the oceans (b) caused the interior of the earth to become hot (c) increased the size of the earth (d) been caused by internal fires.

6. The bottom of the ocean is being mapped by using (a) instruments similar to sonar (b) seismographs and instruments for measuring gravity (c) bathyscaphes (d) Nansen bottles.

7. Scientists hope to learn much about early life in the ocean by (a) analyzing the minerals it contains (b) examining cores of ocean sediment (c) using undersea cameras (d) using the bathyscaphe to examine the floor of ocean trenches.

8. For food all sea animals are dependent upon (a) zooplankton (b) plankton (c) phytoplankton (d) thermoplankton.

9. The food pyramid represents the idea that living things (a) come from other living things (b) originated in the ocean (c) adapt to their environment (d) are interdependent.

10. The main problem in getting minerals from the ocean is (a) finding them (b) extracting them (c) finding a use for them (d) drilling holes deep enough to permit removal of the minerals.

B. Making Comparisons

Compare the science of meteorology with the science of oceanography. Use the outline below in making comparisons.

1. The phenomena with which each deals

2. The basic sciences upon which each depends

3. The types of instruments used in collecting evidence

4. The importance of discoveries which each may make

C. Holding Discussions

Discuss the following questions.

1. Why is there more sodium chloride than any other salt in ocean water?

2. In what way may the metals in discarded tin cans eventually find their way to the ocean?

3. With an increasing number of things depending on the use of water, why isn't the amount of it being greatly reduced?

4. Where would you expect to find the greater erosion of mountains—in the ocean or on land? Why?

5. How do bathyscaphes compare with space ships?

6. Why would research having to do with the behavior of fish be important in making better use of the ocean as a source of food?

D. Building Models

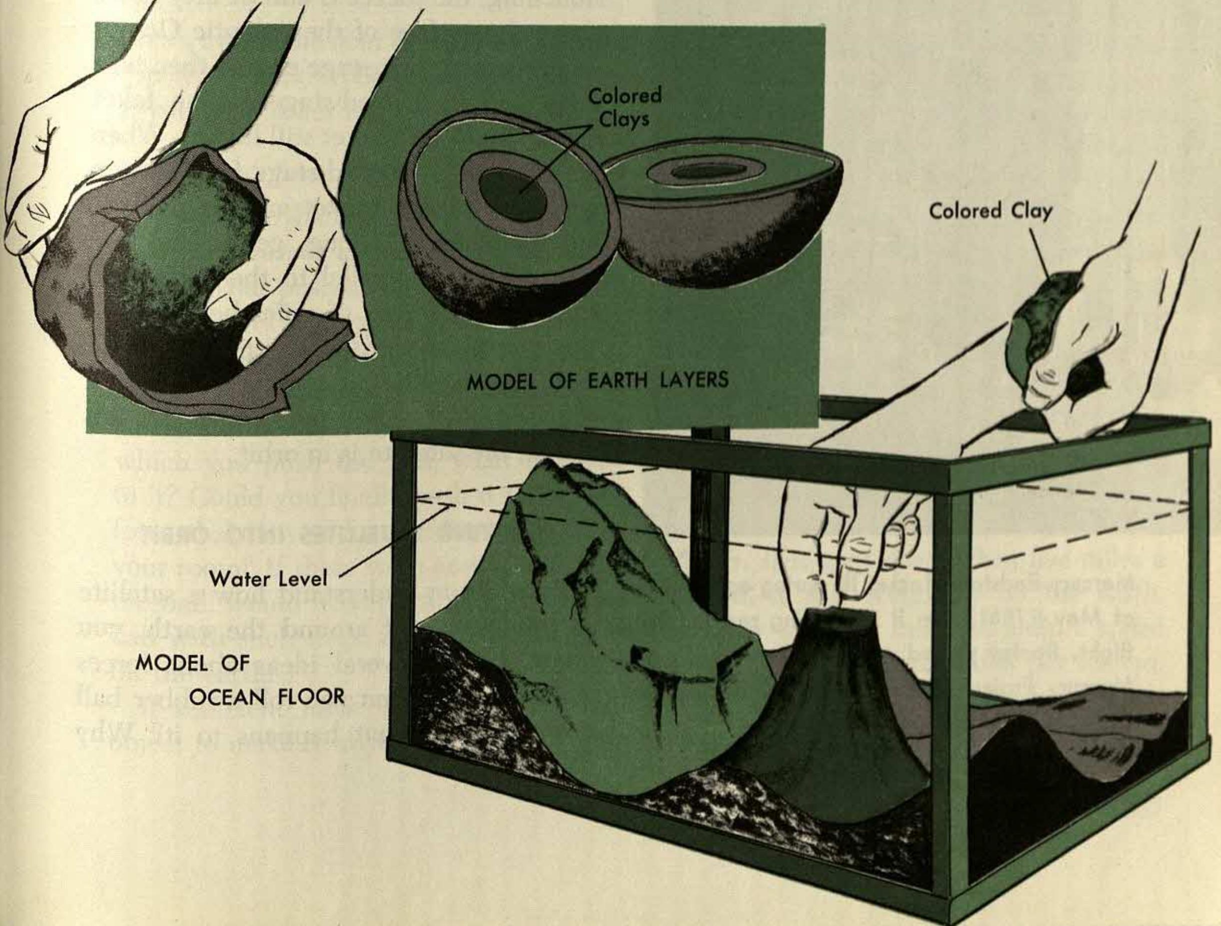
You can build models to show each of the following:

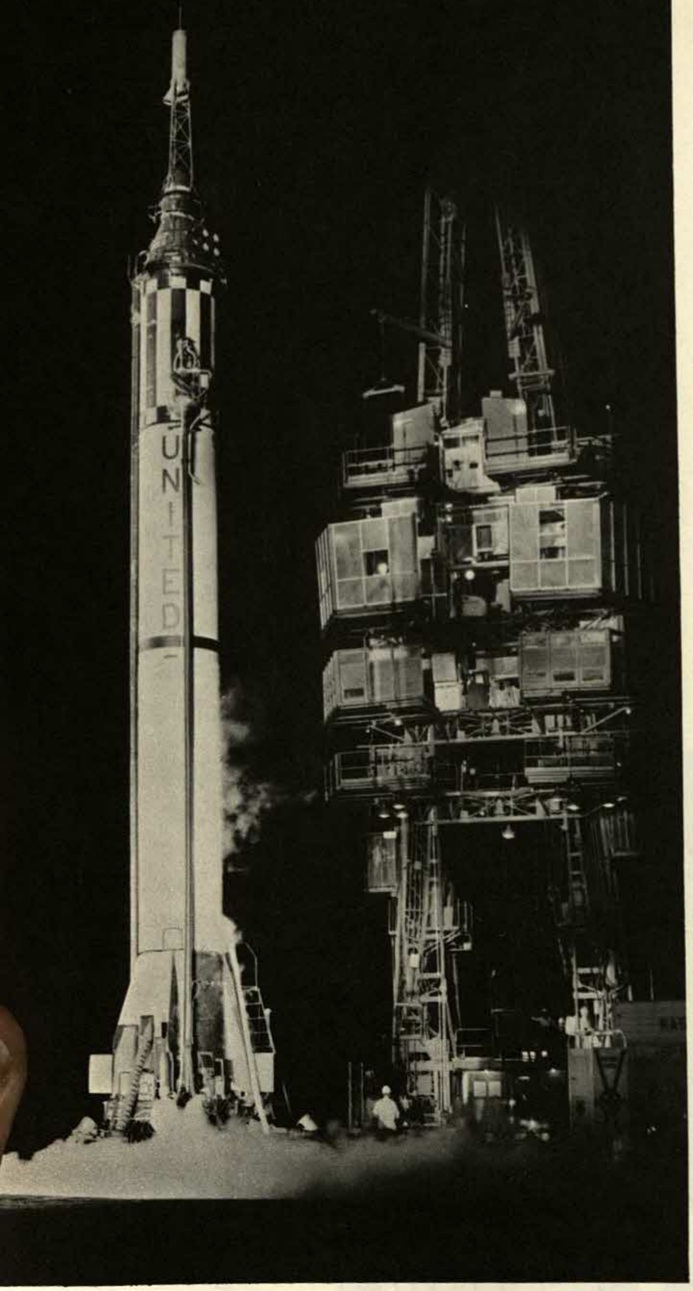
1. The various layers of earth as represented in the diagram on page 287
2. The appearance of the ocean floor
3. The construction of a bathyscaphe
4. A food pyramid

E. Planning Demonstrations

You can plan demonstrations to show:

1. That increasing pressure on a substance increases its temperature.
2. How samples of water can be taken from different depths in the ocean.
3. How the concentration of salt in a water solution can be determined. If you live where you can get sea water, use it.
4. How solid material can be removed from the bottom of a tank. Could your device be used to remove nodules of minerals from the bottom of the ocean?





NASA

Mercury-Redstone Rocket III during early hours of May 5, 1961, when it was being readied for flight. Rocket placed Alan B. Shepard, Jr., in Mercury Project spacecraft into a 5,000-mile-per-hour flight 302 miles downrange.

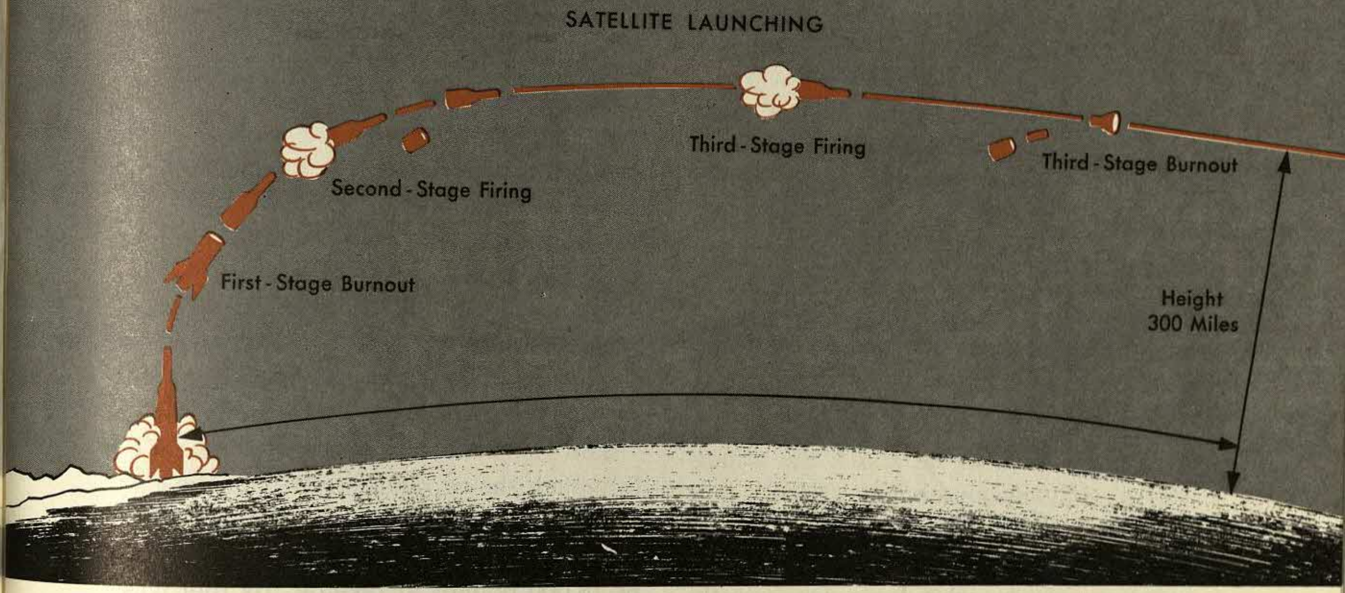
PROBLEM 3: HOW ARE THE FRONTIERS OF SPACE BEING EXPLORED?

". . . Three! Two! One! Zero!" The countdown crackles from the speaker, and in the control bunker, the remote firing button is pressed. The engine starts. The slender, ten-story high, multi-stage, satellite-bearing rocket, surrounded by clouds of smoke and dust, rises from its launching pad on a pillar of flame and climbs up into the sky.

The rocket, moving slowly at first, but with rapidly increasing velocity, is very soon too far away to be seen by the unaided eye. In about one minute after its launching, the rocket is almost fifty miles above the surface of the Atlantic Ocean. Its burned-out first-stage engine then falls away and its second-stage engine takes over to boost the rocket still higher. When the burned-out second-stage falls away a minute later, the rocket and its payload are traveling in a long, gentle arc that soon brings it parallel to the surface of the earth hundreds of miles below it. At this point, the third-stage engine fires to kick the satellite to a final velocity of about 18,000 miles per hour. At this speed, the satellite is in orbit.

PUTTING SATELLITES INTO ORBIT

In order to understand how a satellite is put into orbit around the earth, you must review several ideas about forces and motion. When you roll a rubber ball off the desk, what happens to it? Why



doesn't it hit the floor directly beneath the top of the desk? Where will it hit the floor if you push it harder?

Motion and Force

When the ball leaves the top of the desk, two forces are acting upon it. One force is your push upon it. The other force is the earth's gravity. Each time you push harder (apply more force) to the ball, it falls at a point farther from the table. If you continue to increase the force with which you push the ball, what happens to it? Could you finally push it with such force that it would never hit the floor in your room? If there were no walls to stop the ball, would it be possible to push the ball with such force that it would never hit the earth?

If sufficient force were applied to an object to make it travel at a speed of five miles per second, it would not hit the earth so long as it traveled at that speed. Here is why. The object has two forces acting upon it—one pushing it forward and the other pulling it toward the center of the earth. As soon as the object takes off, it starts falling toward the earth. But the earth is curved. As the object moves forward, the earth curves away from it. At five miles a second, the earth curves away from the object at the same rate that the object falls toward it. Therefore, it never hits the earth.

If the object travels seven miles or more per second, it will leave the earth altogether. If it goes slower than five miles a second, it will eventually hit the earth. In other words, it must maintain a speed between five and seven miles per second. Nothing must slow the object down if it is going to stay in orbit.

Air Resistance

Although air is a gas, it resists the movement of objects through it. You can feel air resistance on your hand as you wave it. Because of air resistance, satellites must be put into orbit out where there is little, or no, air. Rockets must be powerful enough to lift the satellites hundreds of miles beyond the earth. A final rocket must thrust the object into an orbit parallel to the earth. This rocket must increase the speed of the satellite to at least five miles per second before it is on its own.

A satellite that is in orbit far enough above the earth to be above the atmosphere really encounters almost nothing to slow it down and will continue to orbit indefinitely. At only 300 miles high, it must remain in orbit for a few months before it slows down enough to fall back to the earth. At a distance of a thousand miles out in space, the satellite should circle the earth for years.

Thrust of Rocket Engines

From reading the preceding paragraphs, you may get the idea that putting a satellite into orbit is a simple operation. This is not true. There are many problems involved in the operation. The most difficult one has been to build a rocket engine powerful enough to produce the thrust required to carry a satellite out where it can be put into orbit. Why does the thrust have to be so great?

As you will recall from Unit 2, everything is pulled toward the center of the earth by a force called gravity. Furthermore, you learned that the greater the mass of an object, the greater the gravitational force between it and the earth. You also learned that the gravitational force becomes less as the distance between the object and the earth increases. These two ideas explain why it takes so much power to launch a rocket weighing a hundred tons. You know that when you say a rocket weighs a hundred tons, you mean that the earth's gravitational pull upon it is one hundred tons. The rocket engine must, therefore, produce a force of one hundred tons merely to lift the rocket off the ground. However, a much greater force is needed to get it to travel at the speeds required to carry it far above the earth.

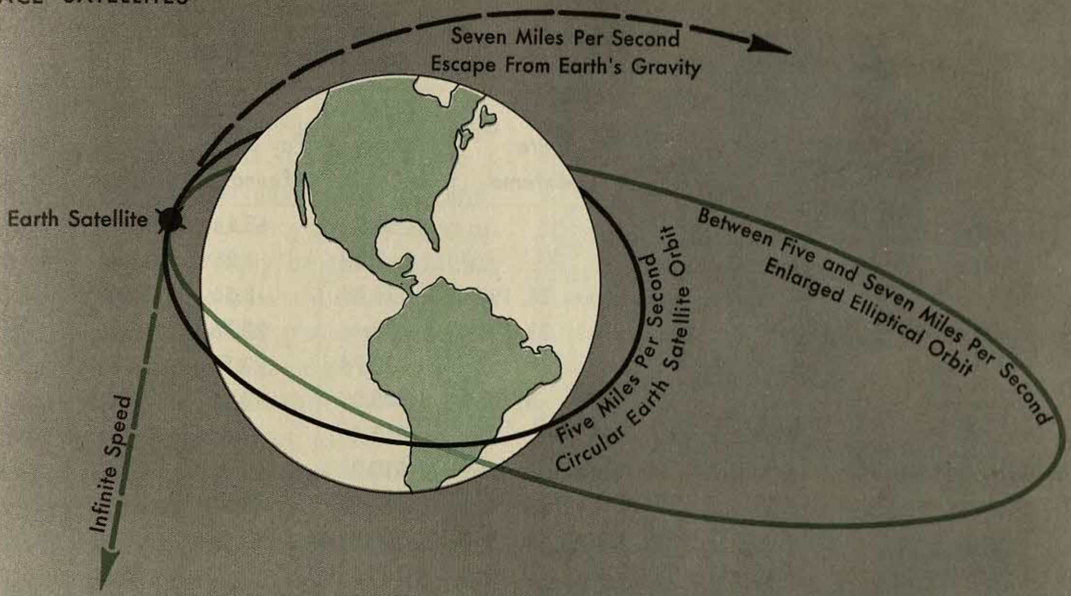
The Redstone rocket, which was used to launch the capsules containing the nation's first two astronauts, weighed 40,000 pounds, and its engines produced a thrust of 78,000 pounds at take-off. Its fuel was burned out in two-and-a-half minutes. In that short time, it carried the capsule to a height of forty miles. It was travelling at a speed of about 4,500 miles an hour.

At present writing, the National Aeronautics and Space Administration is developing two ultra-powerful rockets called Saturn and Nova. These rockets will be true giants compared to earlier ones. Saturn will stand 150 feet tall. It will have a cluster of eight engines, which will yield a combined thrust of a million and a half pounds. Nova will stand 220 feet tall. It will have four engines yielding a combined thrust of six million pounds.

Escape Velocity

If a rocket or a satellite goes into orbit at exactly five miles per second, its orbit will be a circle such as that shown in the diagram on page 589. If it goes seven miles or faster a second, it will leave the

ORBITS OF
SPACE SATELLITES


Seven Miles Per Second
Escape From Earth's Gravity
Earth Satellite
Between Five and Seven Miles Per Second
Enlarged Elliptical Orbit
Five Miles Per Second
Circular Earth Satellite Orbit
Infinite Speed

earth. The speed of seven miles per second is called the ***escape velocity.*** By escape velocity is meant that speed at which a body escapes from the gravitational force of the earth.

Satellites traveling at between five and seven miles per second move in elliptical orbits around the earth. The faster they travel within this range of five to seven miles per second, the more enlarged their elliptical orbits are. In such an orbit, the position closest to the earth is called the perigee and the position farthest from the earth is called the apogee. Satellites travel fastest at the perigee and travel slowest at the apogee.

THE SATELLITE RECORD

On October 4, 1957, the first man-made satellite was put into orbit. Less than four years later, a total of fifty-seven such artificial satellites had been successfully orbited around the earth, forty-five by scientists in the United States and twelve by scientists in Russia.

Four instrument-bearing rockets had also been placed in orbit as planetoids revolving around the sun. Another was made to crash-land on the surface of the moon. Still another was made to circle around the moon at a relatively close distance from it and then to return to an orbit around the earth while its instruments worked continuously to collect data and transmit them to the earth.

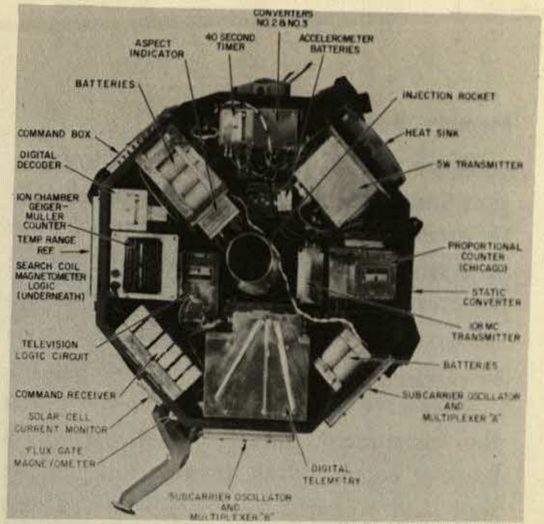
In the spring of 1961, the Russians announced that they had been successful in putting a space ship containing a man into orbit around the earth. After one round trip, he was brought safely back to earth. A few months later, another Russian was reported to have orbited the earth eighteen times before he was brought back.

SUMMARY OF SOME U.S. SATELLITES AND PLANETOIDS ORBITED

Name	*Date Launched*	*Date Reentered*	*Total Pounds in Orbit*	*Pay Load (Pounds)*	*Apogee (Miles)*	*Perigee (Miles)*
Explorer I	Jan. 31, 1958	....	30.8	18.13	1,573	224
Vanguard I	Mar. 17, 1958	....	3.25	3.25	2,453	409
Explorer III	Mar. 26, 1958	June 28, 1958	31.8	18.56	1,746	121
Explorer IV	July 26, 1958	Oct. 23, 1959	38.4	25.76	1,380	163
Vanguard II	Feb. 17, 1959	....	20.74	20.74	2,061	350
Discoverer I	Feb. 28, 1959	Mar. 5, 1959	1,300.0	40.0	605	99
Pioneer IV	Mar. 3, 1959	....	13.4	13.4	Solar	Orbit
Discoverer II	Apr. 13, 1959	Apr. 26, 1959	1,610.0	245.0	225	156
Explorer VI	Aug. 7, 1959	....	142.0	142.0	26,357	156
Discoverer V	Aug. 13, 1959	Sept. 28, 1959	1,700.0	245.0	718	120
Discoverer VI	Aug. 19, 1959	Oct. 20, 1959	1,700.0	....	537	139
Vanguard III	Sept. 18, 1959	....	100.0	50.0	2,329	319
Explorer VII	Oct. 13, 1959	....	91.5	70.0	680	342
Discoverer VII	Nov. 7, 1959	Nov. 26, 1959	1,700.0	300.0	550	104
Discoverer VIII	Nov. 20, 1959	Mar. 8, 1960	1,700.0	....	1,056	120
Pioneer V	Mar. 11,1960	....	94.8	40.0	Solar	Orbit
Tiros I	Apr. 1, 1960	....	270.0	270.0	468	430
Transit I–B	Apr. 13, 1960	....	265.0	265.0	479	233
Discoverer XI	Apr. 15, 1960	Apr. 26, 1960	1,700.0	....	380	110
Midas II	May 24, 1960	....	5,000.0	3,000.0	332	292
Transit II–A	June 22, 1960	....	223.0	223.0	665	389
GREB I	.....do.....	....	42.0	42.0	657	382
Discoverer XIII	Aug. 10, 1960	Nov. 14, 1960	1,700.0	....	436	161
Echo I	Aug. 12, 1960	....	191.4	163.4	1,049	946
Discoverer XIV	Aug. 18, 1960	Sept. 15, 1960	1,700.0	....	502	116
Discoverer XV	Sept. 13, 1960	Oct. 17, 1960	1,700.0	....	472	130
Courier I–B	Oct. 4, 1960	....	500.0	300.0	658	501
Explorer VIII	Nov. 3, 1960	....	90.14	90.14	1,423	258
Discoverer XVII	Nov. 12, 1960	Dec. 29, 1960	2,100.0	....	616	116
Tiros II	Nov. 23, 1960	....	280.0	280.0	453	387
Discoverer XVIII	Dec. 7, 1960	....	2,100.0	....	459	154
Discoverer XIX	Dec. 20, 1960	Jan. 22, 1961	2,100.0	300.0	323	128
Samos II	Jan. 31, 1961	....	4,100.0	400.0	350	300
Explorer IX	Feb. 16, 1961	....	80.0	80.0	1,604	404
Discoverer XX	Feb. 17, 1961	....	2,450.0	300.0	400	201
Discoverer XXI	Feb. 18, 1961	....	2,100.0	300.0	670	150
Transit IIIB	Feb. 21, 1961	....	250.0	250.0	617	104
Telstar	July 11, 1962	....	170	.....	3,500	600

SATELLITE INSTRUMENTS

The instrument package that is built into each satellite is designed to do a specific job. The job may be that of counting meteorites or other particles encountered in space. It may be that of taking radar soundings to measure distance, or it may be that of taking photographs. The job may be that of relaying radio signals from one side of the earth to the other, or measuring temperatures, detecting and measuring different kinds of radiation, or measuring the strength of magnetic fields in the regions of space through which the satellite passes.



U. S. Air Force Photo

Payload of a satellite is a tightly packed instrument package such as the one shown above. It represents the most comprehensive space-gathering data unit that has been devised.

Telemetering Equipment

The satellite also carries radio equipment with which to transmit the information back to receiving stations on the earth. The radios of the earliest satellites that are still in orbit have become silent because they were powered by batteries which eventually ran down. Later satellite radios were powered by solar batteries. For this reason their transmitters can operate indefinitely.

The information is transmitted from a satellite in a ***telemetered signal.*** Telemetering consists of varying a radio signal in patterns that have meaning to those who understand the patterns. In one sense it is somewhat like the Morse code. In another sense, it is somewhat like the way in which you can tell whether a person whose footsteps you hear is coming towards you or going away, rapidly or slowly; or even, whether the footsteps belong to someone you know. For example, a satellite's transmitter may be sending what sounds like a simple succession of "beeps." But because the device in the transmitter that controls the tone of the signal has been designed to be sensitive to temperature-change, changes in the tone of the signal indicate precise temperature information to those who understand what these changes mean. In similar fashion, the device that is triggering the "beeps" may have been made sensitive to another condition so that the duration of the silences between "beeps" conveys other information.

Neither of these two instances lend themselves to critical interpretation by ear alone, but they begin to take on a great deal of precision when they are recorded on tape or in graphs, because in this way the variations that are built into the signal can be carefully measured. Thus, it may take a great deal of time and effort on the part of trained specialists to interpret the signals received from a satellite during just one of its many trips around the earth.

Memory Banks

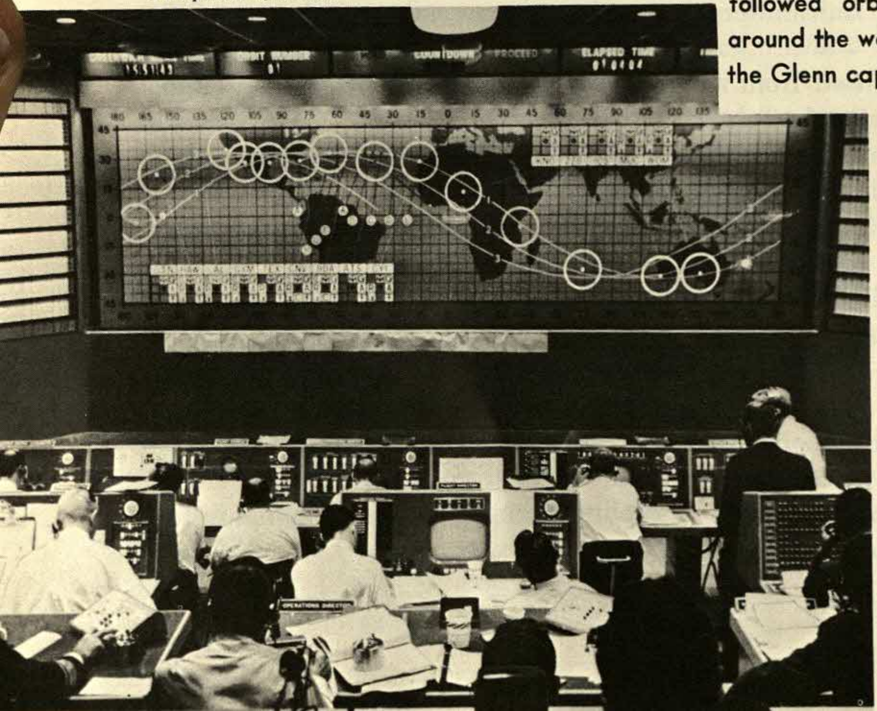
There are other kinds of instrumentation that involve the accumulation of data in ***memory-banks*** in the satellite. These are transmitted only when the satellite is over a ***homing station,*** or in response to a triggering signal which is sent out from the station when it is ready to receive.

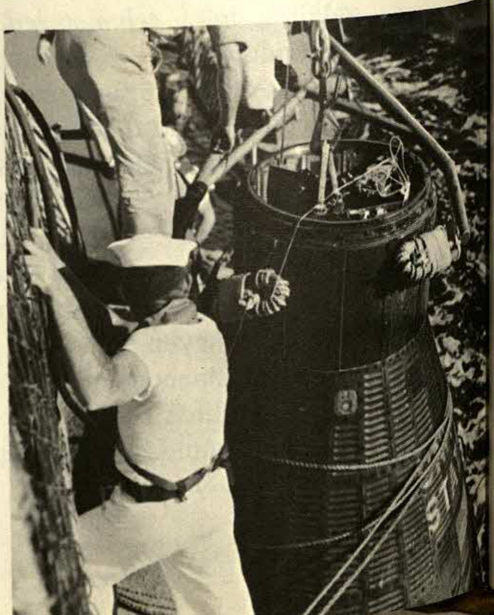
There are even arrangements by which the instrument package itself, with its bank of accumulated information, can be shot back to earth by the satellite. There have been several successful recoveries of such capsules. In July, 1961, an Air Force plane caught, in mid-air, the 300-pound instrument capsule that had been released twenty-nine minutes earlier by a satellite that had orbited the earth thirty-two times. And, of course, the most dramatic instances of capsule-recovery were those made during the spring of 1961 when Americans brought back a man who had been rocketed more than one hundred miles above the earth. A few months later, they brought back a second man. In February, 1962, an astronaut successfully completed three orbits around the earth before being brought back safely.

Distances and Orbits

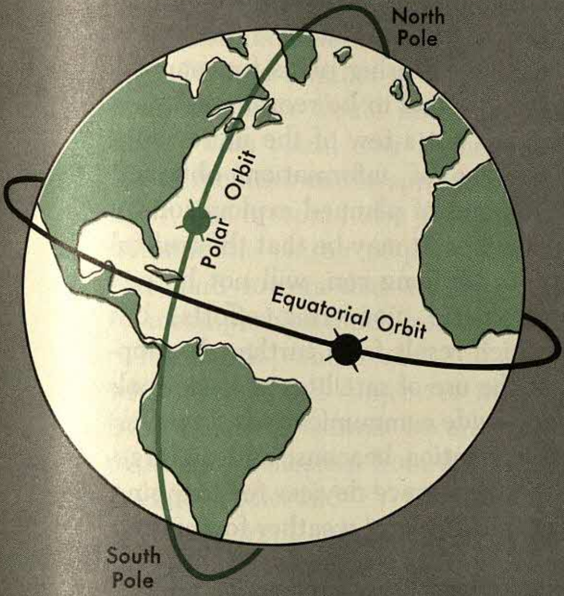
The orbit of the satellite and its distance from the earth determine, as well as the kinds of instruments it carries, the sort of information it can collect. The distance from the earth, for example, determines how long it takes the satellite to orbit the earth. A satellite that is orbiting at a velocity of 18,000 miles per hour will take about ninety minutes for one trip around the earth when it is 200 miles above the earth. It will take about two hours for one trip if it is orbiting about 1,000 miles above the earth. It will take the same satellite twenty-four hours to make one trip if it is orbiting 22,000 miles above the earth.

Two photos by NASA





Mercury-control tracking center, below, left, followed orbital flight of Astronaut Glenn around the world. At right is shown recovery of the Glenn capsule after its descent into sea.



Cloud cover over the Sinai Peninsula and the Red Sea was photographed by satellite Tiros.
NASA

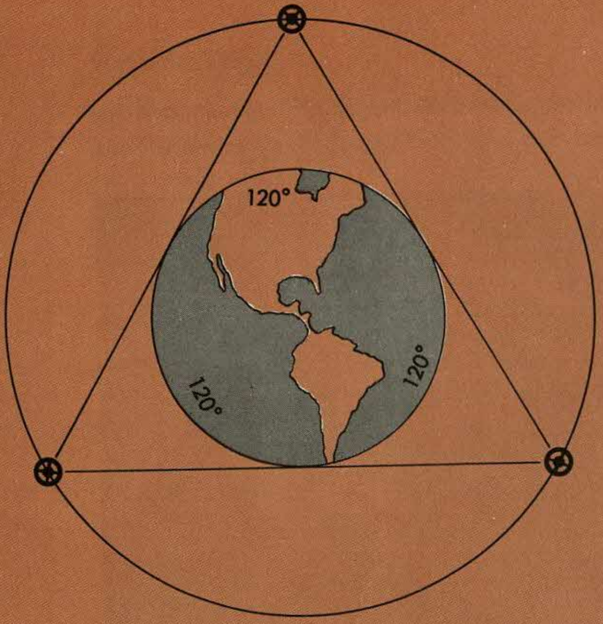
The position of the orbit of the satellite with reference to the axis of the earth determines which portions of the earth the satellite will pass over. If the satellite is in ***polar orbit,*** that is, if its path around the earth lies in a direction that takes it over both the North and South poles on each trip, it can survey the whole of the earth's surface as the earth rotates under it. You can visualize this easily if you spin a globe of the earth with one hand while you make your other hand circle it from pole to pole.

If a satellite is placed so that it orbits the earth right over the earth's equator, or at an angle to it, the satellite can survey specific sections of the earth's surface. Thus, the surface of the earth can be surveyed as a whole, or in part, depending upon the position of the orbit and its distance from the surface.

Midas III, a satellite with instrumentation which can detect missiles as they leave their launching pads, has been put into a polar orbit because it is intended to give warning of the launching of missiles from anywhere in the world. Unconfirmed reports claim that it can pinpoint the location of a glowing cigarette at a distance of eight miles from its receptors.

Tiros III, on the other hand, which is a cloud-cover photographing satellite intended to give early warning of hurricanes, has been put into an orbit that

TWENTY-FOUR-HOUR COMMUNICATION SATELLITES



takes it 48 degrees north and south of the earth's equator. This orbit was selected because it permits the satellite to photograph the belt in which hurricanes occur.

DISCOVERIES AND DEVELOPMENTS

In the few years that artificial satellites have been in existence, man's knowledge of conditions in space and on the earth itself has increased tremendously.

One spectacular instance of information obtained by a satellite was that in the photographs made of the other side of the moon—the side perpetually hidden from view from the earth. A gratifying instance was the discovery of the more accurate shape of the earth, which was determined by direct soundings from a satellite. A disturbing instance was the uncovering of the hitherto unknown Van Allen hard radiation belt surrounding the earth. Because this radiation is dangerous to living things, earlier plans for manned space voyages had to be reexamined.

These are but a few of the more striking examples of information obtained from programs of planned exploration by space satellites. It may be that the fruitful aspects, in the long run, will not be just these dramatic pioneering efforts, but those which result from further development of the use of satellites as basic tools for world-wide communications; as never-failing navigation beacons; and as large-scale reconnaissance devices for mapping, iceberg tracking, and weather forecasting.

Communications Relay Stations

It has been mentioned that a satellite that is 22,000 miles from the earth's surface becomes a twenty-four-hour satellite. Since this is the same time that it takes the earth to rotate on its axis, the net effect is that the twenty-four-hour satellite seems to remain motionless above the same spot on the earth's surface all the time. This means that it will be possible to have stations that stay "fixed" above the earth wherever they are needed. An observer on a satellite that is positioned in this way could view 38.2 percent of the earth's surface, or some 75,000,000 square miles, all the time. Of course, observation would be limited by lack of detail at such a great distance from the earth's surface, but the satellite would serve admirably as a communications relay station.

Three such stations placed 120 degrees apart in the same orbit, as shown in the diagram, could blanket the entire earth with the same radio transmission. Furthermore, they could provide point-to-point communications on the earth with an unlimited number of interference-free channels. This would not only be much better than could ever be hoped for by use of facilities on the surface of the earth itself, but it would also accomplish more without the clutter of poles, oceanic cables, and towers that are now required to accomplish so much less.

Present-day radio and TV are somewhat erratic and subject to interruption from magnetic storms because they depend upon reflection from the ionosphere. Because radio and TV transmitted from, or relayed from, space stations will merely pierce this troublesome portion of the atmosphere, they will be free from today's troubles. Signals that need only pierce the ionosphere require much lower power, and so space communications stations can probably be powered entirely by solar-energy devices.

Navigation Aids

Twenty-four-hour satellites will also provide the world with aids to navigation and air-safety devices that are unmatched on earth today. Because they will remain in relatively fixed positions, and will be observable under all surface conditions, radio beacons from them will make it possible to pinpoint the positions of surface vessels and aircraft with an accuracy never before possible in the history of navigation.

Space Observers

Accurate knowledge of conditions in space will be available on a continuous basis. Scientists will be able to maintain a constant watch upon the radiation that continually bombards the earth. Scientists will be studying the radiation itself and not just the effects it produces in the atmosphere and on the earth.

RESEARCH IN SPACE

A nearly perfect vacuum, a state of almost weightlessness, or a temperature near absolute zero (about 474° below zero Fahrenheit) are good examples of conditions in space which scientists might find useful. Each of these might be made available in a laboratory, but only at the price of the greatest efforts and under very limited circumstances. Research that needs exceedingly low temperatures in the physical sciences will have a brand new start once it can be moved out into space. Unlimited freedom from the restraint of gravity promises to open up whole new experimental fields in the various sciences. Airlessness has become a necessary step for any further significant progress in astronomy.

Airlessness of Space

Vacuums are a requirement in certain kinds of physics research. They are important to research in electronics, where a vacuum tube a mile long can become a reality merely by placing the electrodes a mile apart in the airlessness of outer space.

The most striking instance of the advantages of working in airlessness lies in the field of astronomy. The atmosphere of the earth interferes with observation through ordinary telescopes. Even on a clear, cloudless night, the air continues to be in constant motion due to one cause or another, and interferes at all times with the observation of fine detail in whatever is being viewed.

Both the eye and the camera are affected by the atmosphere. The magnifying power of a telescope becomes useless if what is being magnified is the turbulence of the atmosphere rather than the details of the object that scientists really want to study. The interfering atmosphere is a seriously limiting factor upon the size and usefulness of astronomical telescopes.

Under conditions in which astronomers now work, photographs taken through the very best telescopes, during the finest viewing conditions, show no more detail of the surface features on Mars than one might be able to see with the unaided eye at about 50,000 miles from the planet. For the eye to be able to detect side-by-side objects as separate things, each would have to be about twenty miles in diameter. You certainly cannot consider this to be seeing in detail, because this means that you can't even distinguish objects that are the size of mountains! Yet that represents the very best that scientists can expect if they are restricted to peering at Mars through the earth's atmosphere. If a telescope were put just 300 miles beyond the surface of the earth—the distance from New York to Washington—Mars could be viewed with a clarity of detail obtainable at a naked-eye distance of a very few thousand miles. At that distance, it would be possible to separate, or distinguish, objects a few hundred feet wide.

Only three narrow portions of the entire range of the spectrum of radiant energy come down to earth through the atmosphere. This is the same as saying that scientists have only three little windows with which to "see" beyond the earth. These "windows" are the visible-light band, the high-frequency cosmic ray band, and the high-frequency radio band. The atmosphere either blocks, or absorbs, all other radiation-frequency bands. Hence, scientists who are looking up through the atmosphere remain completely "blind" to the other frequencies of electromagnetic radiation from space. These frequencies cannot be used for the information they might convey.

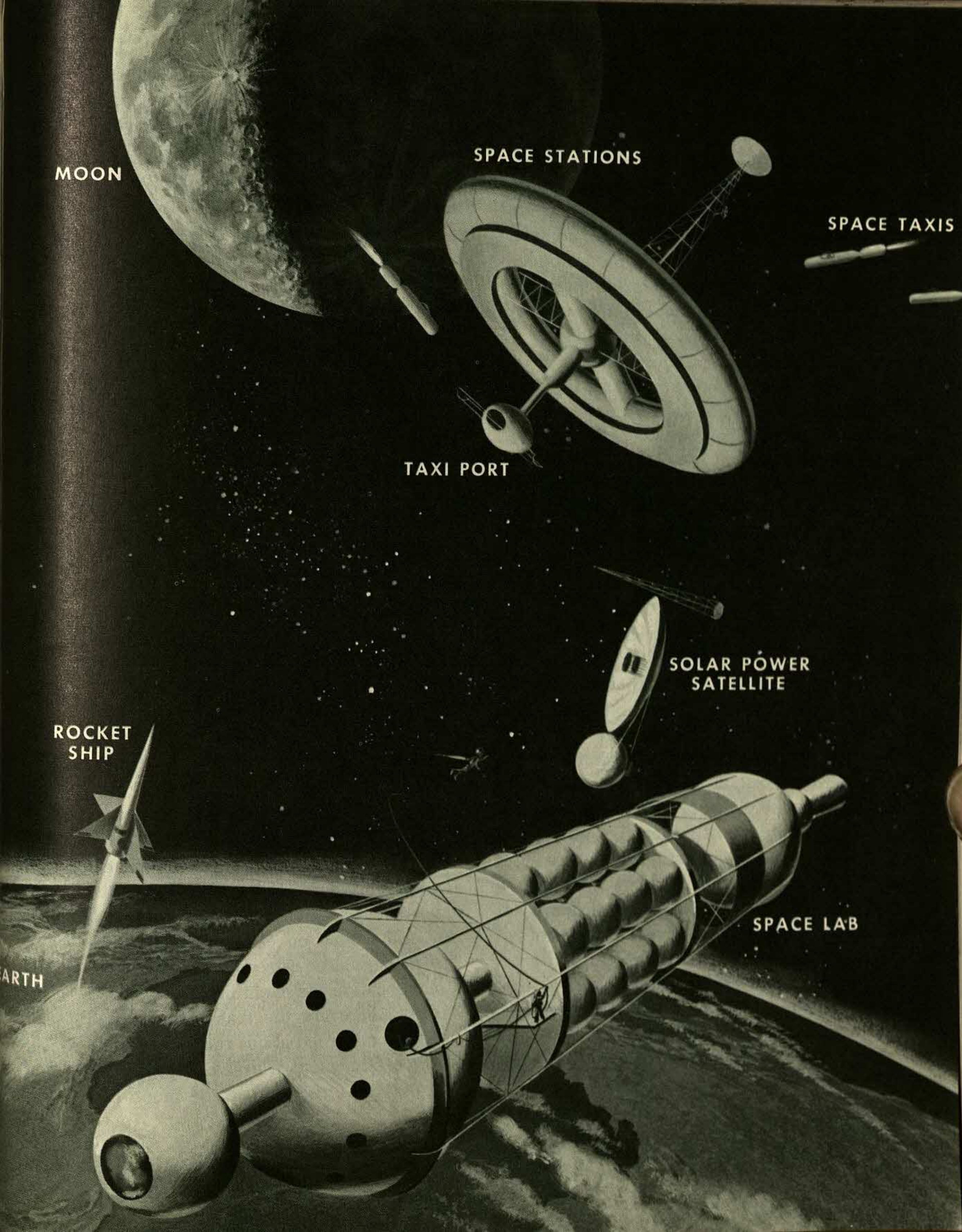
For example, only a portion of the entire radiation spectrum of the sun is received on earth. The high ultraviolet band and other bands higher in frequency, such as the x-ray and gamma ray, are not received because the atmosphere filters them out. While this is beneficial in terms of the survival of living things which might otherwise find these frequencies harmful, scientists also lose the benefit of what they might see with them.

For the same reason, scientists cannot obtain a true analysis of the composition of the stars until spectroscopes can be exposed to those frequencies which are being blocked by the atmosphere. The data concerning the presence of lighter elements in the stars cannot be trusted because the spectrum of substances such as carbon, helium, hydrogen, neon, nitrogen, and oxygen are largely in the high ultraviolet region, which does not come through the atmosphere.

Weightlessness in Space

On earth, a large telescope must be very massive to be rigid. In space, the

Some of the vehicles of space travel in the future are shown in illustration at right.


MOON
SPACE STATIONS
SPACE TAXIS
TAXI PORT
SOLAR POWER SATELLITE
ROCKET SHIP
SPACE LAB
ARTH

rigidity usually required of a very large telescope becomes possible with the lightest construction. A telescope like the Mount Palomar 200-inch reflector, which now uses enormously massive structural members in its mounting, would require practically none in outer space. In fact, its mirror and lenses could be positioned weightlessly in a space orbit and held fixed with respect to one another with the most tenuous of physical connections.

If radio-telescope observatories were moved into weightless positions in space, it would be possible to use antennas miles in diameter. There would be advantages in movability not now available to earthbound radio telescopes which are only a few hundred feet in diameter.

Unlimited Position and Room

So far, the only available picture of the earth as a whole is one that has been put together like a jigsaw puzzle from many bits of information. As yet, no one has ever been able to claim that he has seen the whole earth. To be able to see the whole earth, a vantage point in space would be needed—the room in which, and the position from which, to be able to view the planet in its entirety.

The disposal of radioactive wastes is a great problem on earth. But there will no longer be such a problem when these dangerous wastes can be disposed of away from the earth in the vast reaches of outer space, or, perhaps, even on the sun itself. While scientists must carefully consider the dangers to mankind from the continued testing of nuclear devices on the earth, they can look forward to being able to test the most dangerous devices in the vast emptiness of outer space where there is little, or nothing, to be damaged.

Space in which to work, in which to find vantage points, and in which to put things—literally, space in which to do things in a grand manner and on the largest scale—is the greatest resource available to man in outer space.

THE MOON

People talk about the "race for space" and ask of those who are interested in what lies beyond the earth, "What's your big hurry?" But why shouldn't there be people who want to explore such bodies as the moon? In fact, why shouldn't man hope to be able to make profitable use of the moon some day?

Source of Raw Materials

Using some of man's long-distance knowledge of the moon, consider some of the opportunities it may present. Most obvious of all is the hope that the moon may turn out to be a source of materials that are now scarce, or becoming scarce, on earth, or may even be a source of substances entirely new to the earth.

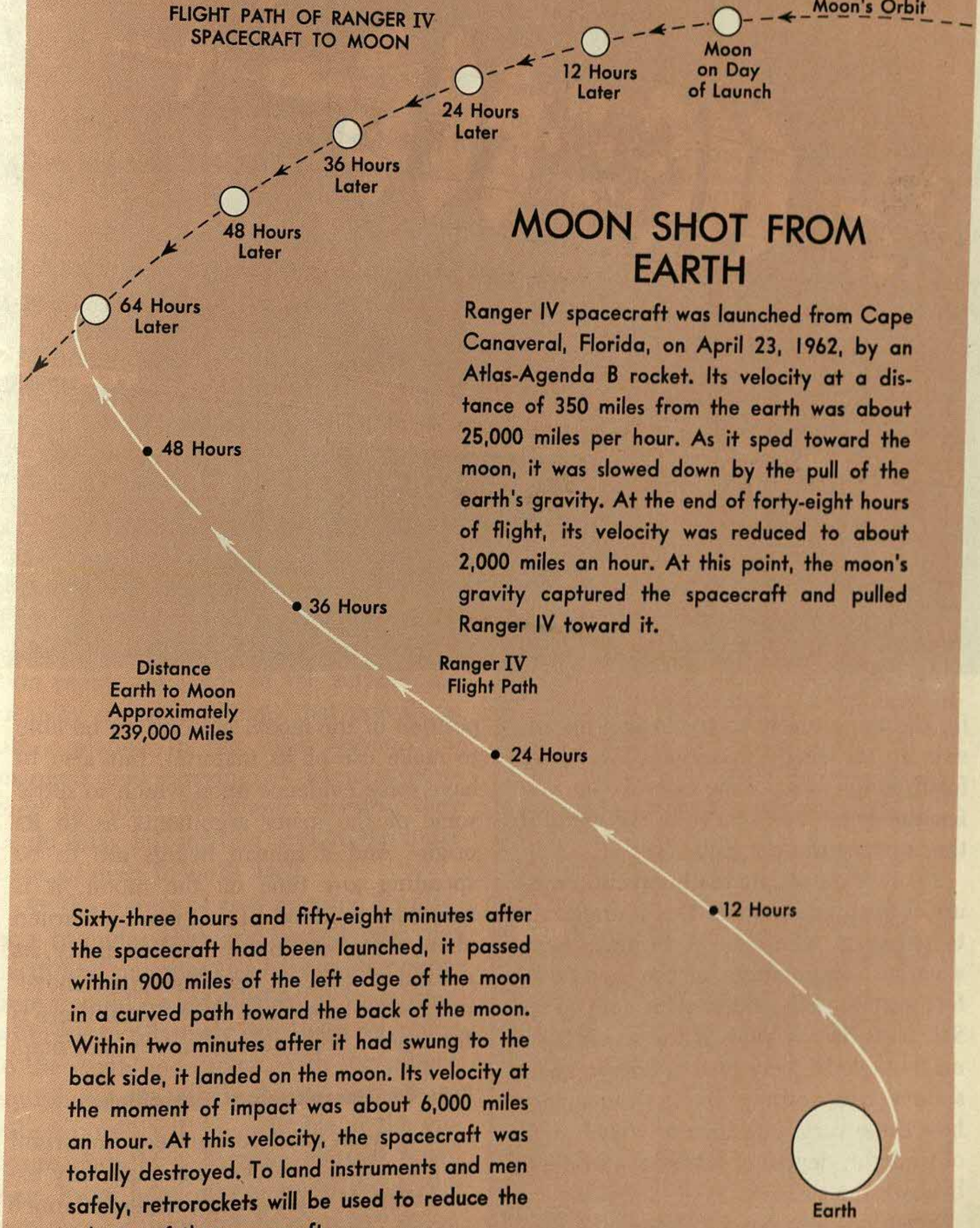
Site of Scientific Endeavors

But greater than the moon's importance as a possible source of raw materials is its importance as a site for doing things that cannot be done on earth now—if ever. The moon will be extremely important as a new location for scientific endeavors.

First, there are the many things that need to be learned about the moon itself. There are scientists who would gladly let themselves be rocketed to the moon just

MOON SHOT FROM EARTH

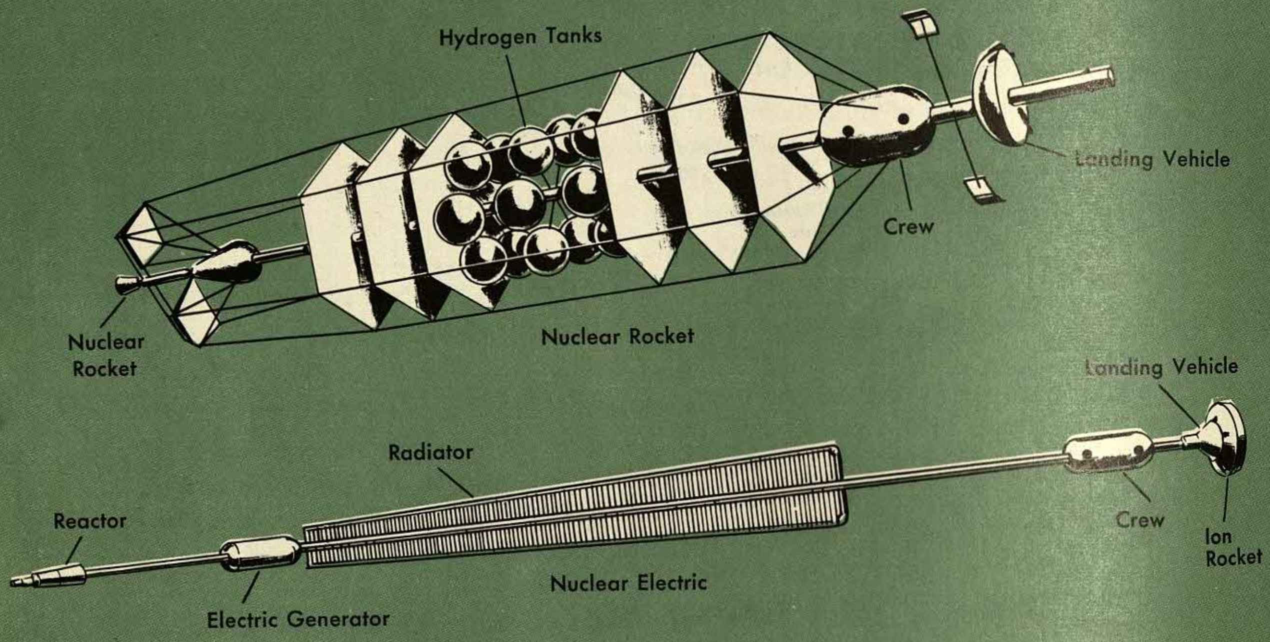
Ranger IV spacecraft was launched from Cape Canaveral, Florida, on April 23, 1962, by an Atlas-Agenda B rocket. Its velocity at a distance of 350 miles from the earth was about 25,000 miles per hour. As it sped toward the moon, it was slowed down by the pull of the earth's gravity. At the end of forty-eight hours of flight, its velocity was reduced to about 2,000 miles an hour. At this point, the moon's gravity captured the spacecraft and pulled Ranger IV toward it.



FLIGHT PATH OF RANGER IV SPACECRAFT TO MOON

Sixty-three hours and fifty-eight minutes after the spacecraft had been launched, it passed within 900 miles of the left edge of the moon in a curved path toward the back of the moon. Within two minutes after it had swung to the back side, it landed on the moon. Its velocity at the moment of impact was about 6,000 miles an hour. At this velocity, the spacecraft was totally destroyed. To land instruments and men safely, retrorockets will be used to reduce the velocity of the spacecraft.

SPACE SHIP STRUCTURES



(Courtesy NASA)

for the opportunity to try to find an answer to the simple question, "Are there fossils in the rocks of the moon?" Can you imagine what it will mean to the world if the answer turns out to be "yes"?

There is, as yet, no really precise measure of the mass of moon. This is important to scientists, who need it to make more accurate computations of the moon's effect on the earth's tides, orbit, and so on. Scientists do not know if the moon has a magnetic field. Very little is known about surface temperatures on the moon, and how these vary with time of "day," angle of sunlight, degree of latitude, and depth beneath the surface.

Scientists also need to know the composition of the moon, not only to be able to make use of its material, but also to have some evidence upon which to settle some of the many arguments as to its origin. And if human beings are to be spending any time on the moon, it is necessary to know all that can be learned about the moon's natural radioactivity, its natural electricity, and the crust movements that take place there. Then there is the moon's other side to survey and map.

Base for Interplanetary Expeditions

The moon can become very important as a starting point for interplanetary expeditions. It will be much easier to launch rockets from the moon. For example, launching velocity for a trip from the earth to the moon is 25,000 miles per hour, but from the moon to the earth is only 7,000 miles per hour. An expedition to Mars or Venus could leave the moon with less fuel and more pay load than it would need if it took off from the earth.

When man becomes established on the moon, the exploration of near-by planets can begin. By the time that man will have become adapted to the moon, the other planets of the solar system will have become important in the ever-expanding reservoir of opportunity available to man.

The lunar base will serve much more efficiently than the earth itself as the launching site for artificial planetoids, planet probes, and ***planetary satellites.*** Planetary satellites are artificial satellites put into orbit around other planets similar to those put into orbit around the earth. They will provide much closer observation points for study of the surface and near-by space conditions that prevail on other planets in the solar system. Unmanned, and carrying TV cameras powered by solar, or atomic, energy, they could relay information back to the lunar base, or even to earth itself.

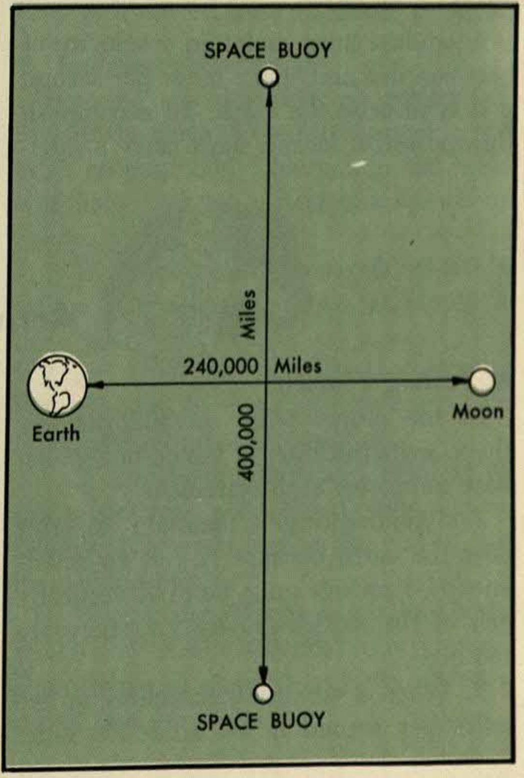
At the points of two opposed equilateral triangles that are formed with the earth and moon as the base-angle points, buoys could be established in space that will remain relatively fixed with reference to the earth and moon. With the proper equipment aboard the buoys, two observation points will be available at the opposite ends of a baseline 400,000 miles long. From here, observers can track objects moving through interplanetary space and compute their distances.

Exploring the Universe

With navigation aids such as these buoys "hanging" at convenient points, the whole of the solar system would become open to routine traffic. When this happens, those to whom the unknown is always challenging; who want to extend their knowledge of the nature of things; who want to make sure of what they only suspect but do not yet know; who want to find ever-new sources of materials and ever-additional living space for humanity; who hope to find other solar systems will already have set their sights beyond the solar system to the great universe outside.

As the British scientist, Arthur Clarke, has put it:

> "We know that the earth will some day become uninhabitable. The sun



> is still evolving and growing steadily hotter. In the future, the oceans will boil back into the skies from which they condensed, and life must pass from the planet earth.
>
> "But the human race will not wait until it is kicked out. Long before then, man will have explored the solar system, and will be making breathless little forays into the abyss that separates him from the stars."

However great the problems of exploring earth's own solar system appear to be now, they are as nothing compared with the job of exploring the Milky Way, earth's Galaxy. Here is a task that will occupy mankind's energies for quite a while.

SUMMARY

A satellite must maintain a velocity of between five and seven miles per second if it is to orbit the earth. To accomplish this, powerful rockets must carry a satellite to a point beyond the earth's atmosphere, where there is little, or no, air resistance.

Many kinds of information are collected by instruments which the satellites carry. Much of the information has to do with conditions in space, but some satellites have been specially instrumented to collect information about conditions on the earth. Information collected by these instruments is transmitted by radio in a telemetered signal to earth-bound receivers.

The period of revolution of an earth satellite depends upon the distance of its orbit from the earth. One that revolves around the earth every twenty-four hours appears to remain in a fixed position above the earth.

Conditions in space, such as airlessness and practical freedom from the earth's gravity, open up opportunities for scientific investigations which are presently impossible, or extremely difficult, for earthbound scientists to conduct.

Activities

A. *Testing Yourself*

In the proper place on your answer sheet, write the letter of the ending which best completes each statement.

1. Satellites cannot maintain an orbit near the earth because (a) of air resistance (b) rockets must be fired vertically (c) of the earth's gravity (d) they are too big.

2. When a satellite is travelling at five miles per second in an orbit 500 miles from the earth (a) it will need additional rockets to keep it going at a constant speed (b) the earth will curve away from it at the same rate at which it is travelling (c) it will soon be destroyed by heat resulting from friction with air molecules (d) it will appear to remain in one place above the earth.

3. Instrument-bearing rockets orbiting around the sun are called (a) solaroids (b) meteroids (c) planetoids (d) asteroids.

4. The instrument package that is built into each satellite is designed to collect (a) only one kind of information (b) all kinds of information (c) specific kinds of information (d) whatever information it can find.

5. A telemetered radio signal is one that (a) gives all of the different kinds of information available (b) is relayed by telephones for a distance of 1,000 meters (c) is powered by solar batteries (d) follows a pattern which has a meaning to those who understand the pattern.

6. The time it takes for a satellite to make one trip around the earth depends primarily upon (a) its shape (b) the resistance it encounters (c) the size of the satellite (d) the size of its orbit.

7. The portions of the earth over which a satellite will pass is determined by its (a) speed (b) size (c) orbit (d) instruments.

8. Observations from a satellite in twenty-four-hour orbit will cover 38.2 percent of the earth's surface. In order to cover the entire surface of the earth with twenty-four-hour satellites, they must be placed at intervals of (a) 120° (b) 90° (c) 180° (d) 360°.

9. The great advantage of a twenty-four-hour satellite in navigation will be that it will (a) always be seen (b) appear to remain in one position in the sky (c) be below the clouds where it can easily be seen (d) remain over the observer as he travels from place to place on the earth.

10. The principal advantage of using telescopes in space will be (a) freedom from atmospheric interference (b) nearness to the stars (c) temperatures near absolute zero (d) reduced gravitational force.

B. Drawing Diagrams

You can answer the following questions by drawing diagrams.

1. Why can satellites, if seen at all, never be seen at midnight, whereas you may see the moon at midnight?

2. Why will an object travelling at five miles per second not hit the earth? Use these facts in planning your diagram.

a. In the first second, a free-falling body will fall sixteen feet.

b. The earth's curvature results in a dip of sixteen feet from the horizontal every five miles.

3. Why would the earth's gravity tend to slow down a satellite as it moved in its orbit from perigee to apogee and speed it up as it moved from apogee to perigee?

C. Interpreting a Table

Ignoring air resistance, all bodies fall toward the earth at the rates shown in the table on page 604. The data in the table will help you to answer the questions below.

1. In a vacuum, how far would a feather fall in two seconds? How far would a dime fall?

2. At what rate does the velocity of falling bodies increase each second? This is called the rate of acceleration.

3. If a body is falling at a velocity of thirty-two feet per second, why has it fallen only sixteen feet at the end of the first second of fall?

4. What is the velocity of a falling body at the end of five seconds? Can you explain why its average velocity is only eighty feet per second?

5. How is the total distance of fall at the end of each time computed from the average velocity?

6. Can you complete the table for six, seven, eight, nine, and ten seconds of fall?

7. What force is adding speed to the falling body?

D. Measuring Forces

If you throw a ball straight up, it will slow down as it rises. Soon it will stop going up and then it will fall to the ground. As soon as the ball leaves your hand, two forces start acting on it. What are they? Which of these forces is greater as the ball rises? At what point are the two forces equal?

Each second, the earth's gravity takes away the same amount of speed from a rising ball that it adds to a falling ball. See the table below. This then means that the time it takes for a tossed ball to reach its highest point is the same as the time that it takes for the ball to fall back to the earth from its highest point. How could you use these facts to tell how high you can throw a ball? How could you check your results to see how accurate your system is? Does it make any difference if you throw the ball straight up, or arch it?

E. Questions for Thought

1. What keeps a satellite going after the rocket that put it into orbit is burned out?

2. Why is the escape velocity on the moon less than on the earth?

3. If an object weighed 160 pounds at the surface of the earth, how much would it weigh 4,000 miles from the earth? 8,000 miles from the earth?

4. Why is it improper to say that gravity is zero in an orbiting satellite? What would be a more proper way of saying it?

5. If there were a hole through the earth at its center, what would happen to a ball if you dropped it into this hole? How could you get it out?

6. What advantage is there to firing a rocket in an easterly direction?

Rate of Fall for Free-Falling Bodies

Time (seconds)	*Velocity at End of Each Interval (feet per second)*	*Average Velocity*	*Distance of Fall (feet)*
0	0	0	0
1	32	16	16
2	64	32	64
3	96	48	144
4	128	64	256
5	160	80	400

Unit Review

A. IDEAS IN SCIENCE

By answering the following questions, you will review many of the important ideas in this unit.

1. How do scientists reconstruct the irrecoverable past?
2. How has soil been formed from igneous rock?
3. Why is four-fifths of the total land surface of the earth made up of sedimentary rocks when the original rocks of the earth were igneous?
4. Why is it believed that coal and oil were formed from living things?
5. In what ways is the earth's surface being leveled?
6. What is believed to cause earthquakes?
7. How has evidence from earthquakes been used to develop hypotheses about the interior of the earth?
8. Why do certain scientists want to drill Mohole?
9. In what ways are living things dependent upon oceans?
10. What two hypotheses have been proposed to explain the origin of oceans?
11. What important discoveries have been made recently about the bottom of the ocean?
12. In what ways are bathyscaphes comparable to balloons?
13. Why are studies of ocean temperatures important?
14. What are food pyramids? Why is phytoplankton at the bottom of the food pyramid of the sea?
15. In what ways could the sea be used more effectively as a source of food?
16. What is the origin of most minerals in the sea? How did they get there?
17. By what methods can minerals be extracted from the sea?
18. How are rockets used to put satellites into orbit?
19. What determines the shape of a satellite's orbit?

20. How have satellites contributed to man's knowledge about the earth?

21. How will the airless condition of space contribute to scientific exploration?

22. How may the condition of weightlessness in space be used?

23. How may the moon be used to advance scientific exploration?

24. Why will new systems of navigation have to be developed when man begins interplanetary travel?

25. Why does man want to visit places such as the moon and planets?

B. Words in Science

Write a sentence which states a relationship between each of the following pairs of words.

1. uranium—lead
2. weathering of rocks—temperature changes
3. igneous rock—sedimentary rock
4. topsoil—subsoil
5. fossils—sedimentary rocks
6. crude oil—gasoline
7. limestone—marble
8. faults—earthquakes
9. oil wells—Mohole
10. oceans—rain
11. volcanic action—oceans
12. cores of ocean sediment—paleontologists
13. ocean temperature—ocean currents
14. phytoplankton—zooplankton
15. energy—food pyramids
16. ocean minerals—solution
17. orbit—gravitational force
18. shape of orbit—velocity of satellite
19. perigee—apogee
20. satellite instruments—telemetered signals
21. telescopes—airless space
22. escape velocity—gravitational force
23. satellites—planetoids
24. observation of satellites—reflected light
25. solar batteries—radio transmission
26. planetary satellites—interplanetary expeditions

You Can Go Further

A. By Preparing Reports

Prepare reports on the following subjects.

a. The selection and training of astronauts
b. Human survival in space
c. International Geophysical Year
d. The training and work of an oceanographer
e. Project Mohole
f. The National Aeronautics and Space Administration
g. The moon shot
h. The construction of a space ship

B. By Preparing Scrapbooks

During the next four or five years, many new developments will be taking place on the ocean and on space frontiers. As these occur, they will be reported in the newspapers. By clipping the reports and arranging them in a scrapbook, you will have a short history of an exciting period in the exploration and development of new frontiers on the ocean and in space.

C. By Examining Reports

The following Congressional reports, prepared by specialists in various aspects of astronautics, are used by Congressmen of the United States to help them make decisions about related legislation.

Space Handbook: Astronautics and Its Application. Staff Report of the Select Committee on Astronautics and Space Exploration. 86th Congress, 1st Session. House Document No. 86. Washington, D.C.: U.S. Government Printing Office, 1959.

The Next Ten Years in Space—1959–1969. Staff Report of the Select Committee on Astronautics and Space Exploration. 86th Congress, 1st Session. House Document No. 115. Washington, D.C.: U.S. Government Printing Office, 1961.

A Chronology of Missile and Astronautic Events. Report of the Committee on Science and Astronautics. 87th Congress, 1st Session. House Report No. 67. Washington, D.C.: U.S. Government Printing Office, 1961.

D. By Reading

Arnov, Boris J., and Mindlin, Helen Mather-Smith. *Inside Our Earth.* Indianapolis: Bobbs-Merrill Company, Inc., 1961.

Factual account of what the interior of our planet is like.

Bixby, William. *Havoc: The Story of Natural Disasters.* New York: Longman's Green Company, 1961.

Eyewitness accounts of volcanic eruptions, tornadoes, and disasters, plus latest scientific explanations.

Buescher, Gustave. *Boys' Book of the Earth Beneath Us.* New York: Roy Publishers, 1961.

Covers development of life on earth and the changing face of our planet.

Cowen, Robert C. *Frontiers of the Sea: The Story of Oceanographic Exploration.* Garden City, N.Y.: Doubleday and Company, Inc., 1960.

Daugherty, Charles Michael. *Searchers of the Sea.* New York: The Viking Press, 1961.

Exciting stories of exploration of the world's oceans and depths.

Haggerty, James J., Jr. *Spacecraft.* Washington, D.C.: National Science Teachers Association, 1961.

Gives the "why" and "how" of space exploration.

Jastrow, Robert, Editor. *The Exploration of Space.* New York: The Macmillan Company, 1960.

Comprehensive survey of recent space developments.

Lent, Henry B. *Man Alive in Outer Space.* New York: The Macmillan Company, 1961.

Story of the pioneers in space medicine.

Roberts, Elliott. *Deep Sea, High Mountains.* Boston: Little, Brown and Company, 1961.

Exciting true stories of operations of the United States Coast and Geodetic Survey.

Sullivan, Walter. *Assault on the Unknown: The International Geophysical Year.* New York: The McGraw Hill Book Company, 1961.

Complete account of the findings of the IGY project.

Vogel, Helen and Caruso, Mary. *Ocean Harvest: The Future of Oceanography.* New York: Alfred A. Knopf, Inc., 1961.

Factual explanation of the sea and its resources.

Wells, Robert. *Alive in Space.* Boston: Little, Brown and Company, 1961.

Introduction to the science of bioastronautics.

DEMONSTRATIONS AND EXPERIMENTS

You can show or find out . . .

That a thermometer measures the temperature of water more reliably than does your hand 14
That the position from which you read a ruler, thermometer, or scale affects the accuracy of your reading 14
How to measure small things 14
What the center of gravity is of an irregularly shaped object 26
What the characteristic action is of charged objects 32
How to separate the compound water into hydrogen and oxygen 37
How to obtain salt crystals from a salt solution 39
How to produce a gas from an acid 48
That heat energy can be changed into work 52
That sound results from using energy to do work 53
How a simple-type chain reaction works 68
How to build a cloud chamber 71
How to graph forces 81
How to demonstrate the law of the lever 95
How the diameter of a siphon tube affects the rate at which water can be removed from a container 104
What will happen when air is pumped through an atomizer 105
That the apparent loss of weight of bodies placed in water is equal to the weight of the water they displace 112
What the effect is upon your body of developing power at different rates 122
That objects of different sizes, shapes, and materials produce different sounds when they vibrate 131
How frequency of vibrations is changed to produce different notes 131
That pitch increases with tension in the vibrating object 131
How to check an imaginary light path with a radiation model 140
How a magnet produces a magnetic field 156
If the direction of the magnetic field depends upon the direction of the electric current 156
That the speed of light through different substances varies 177
How to detect an electric current 220
That a magnetic field will produce an electric current 220
What effect strengthening magnetic field has upon current produced 220
How the number of turns of wire in a coil affects current produced 220
That heat can be obtained from electricity 236
How to make the magnetic field produced by a current-carrying conductor do work 238

That cells connected in series produce a brighter light than cells connected in parallel	241
That an electric current can produce a chemical reaction	241
Which copper wire gets hot sooner—a thin one or a thick one	241
How to compare the amount of heat given off by incandescent lamps of different wattage	246
How to use a scale-drawing system to measure distances	274
That there is a relationship between distance and the angles formed by lines of observation	274–275
How the Ptolemaic system works	283
How to record the path of the moon	305
That the more rapidly something rotates, the greater the centrifugal force, or effect	306
That rays from the sun, when slanted, do not have so great a heating effect as those that strike the earth directly	307
How to build a model solar system, or planetarium	314
How to classify all the nonliving things in your classroom	315
That you see most things, including planets, by reflected light	315
How Mercury's period of rotation and revolution could be the same	315
How to measure the density of different objects	315
That energy from the sun is stored in foods	325
How a reflecting telescope gathers light from distant stars	330
What the magnifying power of a lens is	331
What causes the evaporation-condensation-precipitation cycle	345
How the layers of a hailstone are formed	346
How convection occurs	348
How to make a cloud in a bottle	351
That light rays striking an object at an angle are spread over a larger area	353
How to estimate the altitude of the sun	358
How to be sure you are measuring air temperature	364
How to make weather instruments	374–376
How to find out about local weather changes by a study of tree rings	382
What percent of water from a lawn spray actually gets into the lawn	384
What temperature differences are found in your yard or schoolyard	385
How earthworms, insects, and frogs respond to light, touch, and heat	389
How fast the roots of radishes grow	390
How to classify objects	402
How to collect algae	405
How to grow bread mold	406
How to grow bacteria in a hay infusion	406
Where the plant is in a seed	410
How to make a seed germination test	412
How to observe the growth of seeds planted in soil	413
How planarians propagate	417
What temperature will kill yeast	422

How to observe embryonic development in chicken eggs 422
What a catalyst is 429
That molecules of ammonia gas will go through a membrane 436
How you can observe stomata 439
That digestion of food starts in the mouth 442
That starch will not diffuse through a goldbeater's membrane 444
That iodine will diffuse through a goldbeater's membrane 444
How intensity of light affects photosynthesis 449
That water will diffuse through a carrot root 450
That removal of calcium from a bone softens it 461
What connective tissue in meat looks like 462
Where cartilage and tendons are located in a chicken 465
That fat reduces heat loss 467
How to figure what your average weight should be 468
If a scar is sensitive to touch 471
What an animal brain looks like 472
What happens if you hold your breath 477
Where your thyroid gland is located 478
What the reflexes of a newborn baby are 481
How the pupils of your eye react to light 482
If blinking can be controlled 482
How skin receptors react to pressure, heat, and cold 482
That water is necessary for life 492
How to compare changes in height and weight 494
How to detect misconceptions about different foods 496
How to detect muscle fatigue 497
That saliva will change starch into sugar 518
How to determine the presence of bacteria 518
That flies carry bacteria 519
That some disinfectants control bacteria better than others 519
How fluid in the canals of your ear behaves 522
What happens in your inner ear when you twirl in a circle 537
How to examine human blood 540
How much water expands when it freezes 548
That carbonic acid reacts with limestone 549
That soil is formed from rock 549
That concrete is affected by weathering 550
How topsoil differs from subsoil 551
How a seismograph works 563
What the various layers of the earth are 585
That increasing pressure on a substance increases its temperature 585
How samples of water can be taken from different ocean depths 585
How the concentration of salt in a solution can be determined 585
What the acceleration rate is of falling bodies 603
What force adds speed to a falling body 604
How to measure forces 604

Glossary

Because new science words are thoroughly defined and developed in the text, it has been possible to limit this glossary to those words infrequently used, or especially difficult or abstract. Many of these words have other meanings, which can be found in a large dictionary. The page number after each definition tells you where the word is used.

Here is a key to the special spellings used after the words. They will help you pronounce the words correctly.

a as in **fat**
ā as in **āpe**
â as in **bâre**
ä as in **cär**
e as in **ten**
ē as in **ēven**
ê as in **hêre**
ẽ as in **ovẽr**
i as in **is**
ī as in **bīte**

o as in **lot**
ō as in **gō**
ô as in **hôrn**
o͞o as in **to͞ol**
oo as in **look**
oi as in **oil**
ou as in **out**
u as in **up**
ū as in **ūse**
ũ as in **fũr**

g as in **get**
j as in **joy**
y as in **yet**
ch as in **chin**
sh as in **she**
th as in **thin**
zh as in **leisure**
ŋ as in **ring**
ə for a in **ago**
' as in **able** (ā'b'l)

absolute humidity: The actual amount of water vapor in the air at any one time, 367.

absolute zero temperature: Zero on the absolute temperature scale. Theoretically, –273.16°C—the lowest possible temperature, 255.

acceleration: Time rate of change of speed, 61.

acid: Substance containing hydrogen, which is capable of being replaced by a metal to form a salt, 25.

airfoil: Any surface, such as a wing, designed to help in lifting, or controlling, the airplane in flight, 100.

air mass: A large body of air having about the same temperature throughout, 360.

alga (al'jē): Subdivision of Thallophyta, distinguished from rest of Thallophytes by presence of chlorophyll, 396.

alpha particle: Positively charged nucleus of the helium atom, consisting of two protons and two neutrons, 58.

altitude (of a star): Angular elevation above the horizon, 269.

amino acids: Organic acids which are the fundamental constituents of living matter, 432.

ampere (am'pêr): A unit used in measuring electric current, 229.

amplitude: The extent of a wave action in opposite directions from a central position, 127.

angstrom (aŋ' strəm): A unit used especially for measurement of light-wave length, 172.

antibodies (an'ti-bod-ēz): Chemical substances produced by body cells to counteract harmful materials which get into the body, 506.

antitoxin: A substance capable of neutralizing a given toxin, 506.

aphelion (a-fē'li-ən): Point in earth's orbit that is the greatest distance from the sun, 293.

apogee (ap'ə-ji): That point in the orbit of a celestial body at the greatest distance from the earth, 294.

armature (är'mə-chẽr): The rotating core in a generator or motor, 219.

atomic mass unit (amu): The mass of an atom, compared to carbon, 62.

atomic number: The number which represents the positive charges (protons) in the nucleus of an atom, 37.

axon: Efferent process of nerve cell, 459.

azimuth (az′ə-məth): Angle between the vertical plane containing the line, or celestial body, and the plane of its meridian, 269.

base: Substance which forms a salt and water only when reacting with an acid, 25.

beta particle: An electron in a beta ray, 58.

betatron: An electromagnetic apparatus for liberating electrons and accelerating them to a required velocity for discharge against a chosen target, 62.

buoyancy: Upward force exerted by fluid on object floating on, or submerged in, it, 106.

British thermal unit: Amount of heat required to raise one pound of water 1° F, 77.

calorie: The large Calorie is the amount of heat required to raise the temperature of 1 kilogram of water 1° C. The small calorie is 1/1000 of the large Calorie, 77.

calorimeter (cal-ə-rim′ə-tẽr): An apparatus for measuring the quantity of heat generated by friction, combustion, or chemical change, 257.

capacitor (kə-pas′ə-tẽr): A device made of two metal plates separated by an insulator, and used for storing electric energy, 150.

catalyst (kat″l-ist): A substance which changes the rate at which a chemical reaction occurs, but is, itself, unchanged at the end of the reaction, 429.

cell (biological): The smallest unit of a living thing, 398.

cell (electric): A device which generates electricity, 228.

centrifugal effect (sen-trif′ə-gal): The force which tends to make a whirling object fly outward from the center, 287.

cerebellum (ser-ə-bel′əm): A large expansion of the hind brain, concerned with the coördination of voluntary movements, posture, and balance, 472.

cerebrum (ser′ə-brəm): The upper front part of the brain, consisting of two hemispheres. It is the chief center for learned responses, 472.

chemical change: Change in a substance involving an alteration in its chemical composition because of an increase, decrease, or rearrangement of atoms within its molecules, 40.

chemical formula: Method of expressing a molecule of a compound by using the symbols of each of the elements of the compound, 30.

chemical symbol: A letter, or letters, which represent an atom of an element, 29.

chlorophyll (klôr′ə-fil): Green coloring matter in plants, 400.

compound: A chemical substance made up of two or more different elements, 29.

conditioned reflex: A reflex that has been built up through continued experience, 475.

cosmic ray: Radiation, composed mainly of charged particles, that falls upon the earth from outer space, 204.

coulomb (ko͞o-lom′): The amount of electricity transferred by one ampere in one second, 243.

covalence: A bond formed by the mutual sharing of electrons between the atoms of a compound, 36.

cryogenics (krī-ə-jən′iks): Branch of physics dealing with extremely low temperatures, 256.

cyclotron (sī′klə-tron): A device for increasing the speed of particles used to bombard the nuclei of atoms, 62.

cytoplasm (sī′tə-plaz′m): The entire protoplasm of a cell except the nucleus, 400.

decibel (des′ə-b′l): The unit used to compare, or indicate changes in, levels of intensity of sound, 127.

dendrite (den′drīt): The branching portion of a nerve which picks up the stimulus and transmits it to the nerve cell, 459.

dew point: The temperature at which dew forms, or condensation occurs, 343.

diastrophism (dī-as′trə-fiz-′m): Movements of the earth's crust, which cause vertical, or horizontal, changes in position, as well as deformation of rocks, 561.

diffusion: The spreading of a dissolved substance through the solvent by random movement of its molecules, 434.

drag: The force exerted on an airplane, which tends to reduce the forward motion of the plane, 121.

dyne: A force which, applied to a mass of one gram for one second, gives it a velocity of one centimeter a second, 24.

effector: An organ tissue that carries out a response to a nerve impulse such as a muscle or gland, or a cell that carries out a response to a nerve impulse, 528.

electric current: A stream of electrons flowing through a conducting body, 218.

electric field: A space in the vicinity of an electric charge, which shows itself as a force on an electric charge in that space, 148.

electrolysis (i-lek-trol′ə-sis): The decomposition of a chemical compound by the passing of an electric current through it, 36.

electromagnetic spectrum: The result obtained when radiations of electromagnetic waves are resolved into their wave lengths, or frequencies, 138.

electron: A part of an atom which swings about the nucleus. It has a negative charge, 13.

electrovalence: A bond formed by the complete transfer of electrons from the atoms of one element of a compound to the atoms of another element, 36.

element: The smallest unit that combines with other such units in the formation of chemical compounds, 4.

embryo (em′bri-ō): An organism in the earlier stages of its development, 411.

endocrine gland (en′də-krin): One of several ductless glands, the internal secretions of which are released directly into the blood or lymph, 478.

energy: The capacity for exerting a force through a distance, and thus doing work, 4.

engine: Any mechanism, or machine, designed to convert energy into mechanical work, 113.

enzyme (en′zim): A complex substance produced by cells, and having the power to start, or speed up, chemical reactions in animals (such as digestion) and plants, 428.

epithelium (ep-ə-thē′li-əm): Any tissue which lines the cavities and tubes and covers exposed surfaces of the body, 456.

equilibrium: State of balance between opposing forces, or actions, 84.

erg: The work done by a force of one dyne acting through a distance of one centimeter, 61.

erythrocyte (i-rith′rō-sīt): One of the red corpuscles of the blood, 463.

fault: A break in the continuity of a body of rock, or of an ore vein, with dislocation along the plane of fracture, 562.

fission (of a cell) (fish′ən): The process whereby microörganisms multiply by cell division, 405.

foot candle: A unit for measuring the amount of illumination from a light source, 184.

force: A pull or a push exerted by something, 21.

fossil: Any remains, impression, or trace of an animal or plant of a former geological era, 551.

frequency: The number of cycles occurring in a second, 123.

friction: Resistance to motion, due to the contact of two surfaces moving relative to each other, 249.

front: The surface of air separating a cold air mass from a warm air mass, 361.

fulcrum: The support, or point of rest, on which a lever turns in a moving body, 84.

fungus (fuŋ′gəs): A simple plant that lacks chlorophyll and lives upon dead or living organic matter, 405.

galaxy (gal′ək-si): Any of the very large systems of stars, nebulae, and other celestial bodies. The solar system is in the Milky Way galaxy, 320.

gamma ray: A type of radiant energy issuing from certain radioactive substances, 58.

ganglia (gaŋ′gli-ə): A collection of nerve cells outside the brain and spinal cord, 524.

generator: A machine which converts mechanical energy into electrical energy, 106.

genus (jē′nus): A class of plants and animals ranking next above the species and next below the family, 395.

glucose: The most common simple sugar and the chief fuel substance of most organisms, 427.

glycogen (glī′kə-jən): A white, complex sugar contained in animal tissues and usually stored in the liver. It is sometimes called animal starch, 445.

gravitational field: A field in which any two bodies are attracted to each other in proportion to the matter they contain, 21.

gravity: The force of attraction by which terrestrial bodies tend to fall toward the center of the earth, 20.

homeostasis (hō-mē-ō-stā′sis): A condition in which relative constancy is maintained within the organism despite environmental changes, 520.

hormones: Chemical substance produced by special glands in the body, and which control certain bodily activities, 478.

horsepower: A unit for measuring power, equal to 33,000 pounds lifted one foot in one minute, 79.

igneous (ig′ni-əs): Formed by the action of a fusing heat, particularly rocks consolidated from a molten state, 547.

immune: A person not susceptible to some particular disease, or protected from disease by inoculation, 506.

inertia: The tendency of any object to continue to move once it is in motion, or to remain at rest once it has stopped moving, 116.

instinctive behavior: A response that is independent of any previous experience or learning, 528.

interferometer (in-tĕr-fêr-om′ə-tĕr): A device by which it is possible to measure the angular diameters of certain giant stars, 322.

invertebrate (in-vũr′tə-brāt): An animal without a backbone, 578.

ionized: Changed into the form of ions, 341.

ion: An electrically charged atom formed by the loss, or gain, of electrons, 35.

isotope: Atoms of the same element, and having the same atomic number, but differing in atomic mass units, 59.

joule (jo͞ol): The work done in one second by a current of one ampere flowing through a resistance of one ohm; the CGS unit of work or energy, 75.

Kelvin scale: Absolute scale of temperature, 255.

kilowatt-hour: A unit for measuring both the amount and the rate at which electricity is used, 118.

kinetic energy: The capacity for doing work, which is possessed by a substance because of its motion, 52.

larva: The first stage of an insect after leaving egg; young of any invertebrate animal, 511.

leucocyte (lo͞o′kə-sīt): One of the white, or colorless, corpuscles of the blood, 463.

lever: Mechanical device consisting of a rigid bar turning freely on a fixed point, or fulcrum, 84.

linear accelerator: Apparatus for accelerating ions to high energies, 61.

lymph: A colorless fluid which aids in transporting materials in the body, 463.

magnetic field: Space in which a magnetic force, such as that around a magnet, exists, 150.

magnetism: The characteristic properties possessed by magnets, 150.

mantle: The intermediate zone of the earth between the crust and the iron-nickel core, 568.

mass: The quantity of matter of a substance, 24.

matter: Anything that has weight and occupies space, 4.

megacycle: Measure of frequency of high-frequency electric alternating current, equal to one million cycles, 167.

meridian: An imaginary circle around the earth, or on the celestial sphere, which passes through both the North and South Poles, 267.

meson: Particle found in cosmic rays, and having a mass intermediate between that of the electron and the proton, 205.

metamorphic (met-ə-môr′fik): Pertaining to, or characterized by, change of form; applied to a rock, the constitution of which has undergone pronounced alteration, 547.

meteorite: A mass of stone, or metal, that has reached the earth from outer space, 302.

microörganism: Any extremely small plant or animal organism, especially one visible only in an optical or electron microscope, 499.

microwave: A radio wave with a high frequency and short wave length, 166.

mixture: Two or more substances which, when put together in varying proportions, retain their individual chemical properties, 28.

model: An object, usually small, representing accurately something to be made, or already existing, 21; a way of thinking, e.g., the astronomer's system of the celestial sphere, 268.

molecular formula: Formula of a chemical compound, showing the kind and number of atoms present in the molecule, but not their arrangement, 41.

molecule: The smallest part of a substance which still maintains the properties of the substance, 29.

nebulae (neb′yoo-lə): Clouds of gases in outer space that glow from the light of stars that lie within, or near, them, 324.

neuron: A nerve cell with all its processes and extensions, 459.

neutralization: Addition of acid to alkali, or vice versa, until neither is in excess and the solution is neutral, 45.

neutron: An electrically neutral particle of the atom, 33.

non-metal: A chemical element not possessing the properties of the metals, 36.

nuclear fission: The breaking up of a heavy atom, e.g., uranium, into two or more new atoms of approximately equal mass, with an enormous release of energy, 63.

nuclear fusion: A thermonuclear reaction in which the nuclei of a light element undergoes transformation into those of a heavier element with the release of an enormous quantity of energy, 65.

nucleoplasm: The substance of the nucleus of a cell, 400.

nucleus (of an atom): The central core of an atom, composed of protons and neutrons, 33.

nucleus (of cell): A small body within a living plant or animal cell, which controls many of the cell's activities, 400.

ohm: A unit for measuring the resistance of a material to electricity, 237.

organism: Any form of animal or plant life, 499.

ovary: The organ in plants or animals that produces eggs, 410.

overtone: Vibrations which are small, whole-number multiples of the lowest frequency contained in a musical tone, 128.

ovule: The body within the ovary which, upon fertilization, becomes the seed, 410.

pancreas: Gland situated near stomach, 443.

parallels of latitude: Imaginary circles around the earth, with all points on any one circle equal distances from, or parallel to, the equator, 266.

parasite: An animal or a plant that lives on, or in, another organism, 501.

parathyroid gland: Several small glands lying near the thyroid gland, 478.

percussion: The sharp striking of one body against another, which causes a shock or a sound, 251.

perigee (per'ə-jē): The point in the orbit of the moon at which it is nearest the earth, 294.

perihelion (per-ə-hē'li-ən): The point in the orbit of a planet or comet at which it is nearest the sun, 293.

phloem (flō'em): Plant vascular tissue through which fluids pass from shoot to root, 440.

photoelectric effect: Any effect arising as a result of a transfer of energy from light striking a substance to electrons in the substance, 152.

photon: A quantum of radiant energy moving with the velocity of light and with an energy proportional to its frequency, 153.

photosynthesis: The process in green plants which uses light to form carbohydrates from carbon dioxide and water, 427.

pineal body: A body of unknown function present in the brain of all vertebrates having a cranium, 480.

pitch (musical): Highness or lowness of a sound, determined largely by its frequency, 128.

pituitary gland: A small, oval, endocrine gland attached to the base of the brain, 479.

plasma: The clear, fluid portion of blood, freed from blood cells and used for transfusions, 444.

pollination: The transfer of pollen from the male part of the flower to the female part, 411.

potential energy: The capacity for doing work, which does not show itself except under proper conditions, 51.

poundal: That force which, acting on a mass of one pound, will impart to it an acceleration of one foot per second per second, 24.

power: The rate at which work is done, 74.

precession (pri-sesh'ən): The slow revolution of the earth's axis in a small circle about the pole, 294.

proton: One of the elementary particles in nucleus of an atom. It has a positive charge, 33.

protoplasm: The basic, living substance in all cells, 400.

protozoan: Single-celled animal such as amoeba, 500.

quantum: A unit of radiant energy released by an atom when one of its electrons falls from an outer to an inner orbit, 152.

radar: Device which detects the presence, and indicates the position, of objects by measuring the interval between the emission and return of high-frequency radio waves, 167.

radiation: The emission of any rays, wave motion, or particles from a source, 58.

radical: A group of atoms which acts as a unit in a compound, and may either pass unchanged through a series of reactions, or be replaced as though it were a single atom, 45.

radioisotope: A radioactive isotope, usually one produced artificially from a normally stable element. It is extensively used in biological and physical research for diagnostic and therapeutic purposes, 67.

receptor: Terminal structure, or free nerve ending, which is specialized to receive various forms of external and internal stimuli, 482.

reflex: An involuntary action produced when a stimulus is directly transmitted by a nerve center to a muscle or gland, 474.

refraction: Bending of light rays when they pass through substances of different densities, 175.

relative humidity: A comparison of the amount of water vapor in the air with the total amount the air can hold at its temperature, 367.

resistance (in electricity): The opposition, expressed in ohms, offered by a body to the passage through it of an electric current, 237.

retina: The inner membrane at the back of the eyeball, containing the light-sensitive rods and cones, which receive the optical image, 179.

seismograph (sīz'mə-graf): An instrument for automatically recording the intensity, the direction, and the duration of an earthquake shock, 563.

sensory nerve: A nerve which either acts as a receptor itself, or receives excitation directly from a receptor, 524.

serum: The more fluid constituent of blood, lymph, milk, and similar animal liquids, 507.

sexual reproduction: Reproduction resulting from the union of a male and female sex cell, 411.

short circuit: A path of low resistance established between any two points in an electric circuit, 225.

solar eclipse: The dimming, or elimination, of light reaching an observer by the passage of the moon between the sun and the observer, 298.

species: The smallest unit of classification commonly used, e.g., the group whose members have the greatest mutual resemblance, 395.

specific gravity: The ratio of the mass of a body to that of an equal volume of some standard substance, e.g., water, 25.

spectroscope: An instrument which divides radiant energy, such as light, into its different wave lengths, 276.

spectrum: The band of color from violet to red observed when white light is passed through a triangular-shaped piece of glass, 276.

spore: Single-celled, or several-celled, reproductive body that becomes detached from the parent and gives rise either directly, or indirectly, to a new individual, 405.

spring equinox: The time—March 20-21—that the earth's axis makes a 90° angle with a line drawn to the sun, and neither the North nor the South Pole has any inclination toward the sun, 290.

stamen: The pollen-bearing organ of a flower, standing inside the floral envelope and consisting of two parts, the filament, or support, and the anther, or pollen sac, 411.

sterile: Anything that has nothing alive in it, or on it, 408.

structural formula: Pertaining to, or denoting, the spatial arrangements of atoms in a molecule, 43.

subscript: A small letter, or number, written after, and following, a chemical symbol, 30.

synapse (si-naps'): The point of contact between two neurons, 474.

telemetered signal: A signal which activates an electrical apparatus for indicating, or measuring, various quantities and transmitting the data to a distant point, 591.

tensile strength: Resistance of a material to forces of rupture and longitudinal strength, 25.

thrust: linear force generated by an engine-driven propeller, or by exciting gases, 121.

tissue: A group of similar cells doing the same kind of work, such as a muscle, 456.

torque: In a machine, the product of a force by its perpendicular distance to the fulcrum, thereby being a measure of the rotational effect of the force, 84.

tracer element: A radioactive element used to study biological, chemical, or industrial processes by following its path on a film, fluoroscope, or other detection device, 67.

transformer: An electric device by which an alternating current of one voltage is changed to another, without alteration in frequency, 222.

transistor: A miniature amplifying device that performs nearly all of the functions of the electronic vacuum tube, 159.

transpiration: Evaporation of water from leaves and other exposed surfaces of a plant, 437.

turbine: Any motor in which a shaft is steadily rotated by the impact of a current of steam, air, water, or other fluid directed from jets, or nozzles, upon blades of a wheel, 106.

unit: A standard quantity with which others of the same kind are compared for purposes of measurement, 11.

vector: A line representing a physical quantity, which has magnitude and direction in space, as velocity, acceleration, or force, 81.

velocity: The rate of motion in a stated direction, measured as length per unit time, 78.

virus: Disease-producer too small to be seen by ordinary microscopes, 500.

vitamin: Any of a group of complex organic substances found in minute quantities in most natural foodstuffs, and closely associated with the maintenance of normal physiological functions in man and animals, 496.

volt: A unit for measuring the electromotive force, 222.

watt: The practical unit of electric power, activity, or rate of work, 245.

watt-hour: Electrical energy equal to that represented by one watt acting for one hour, 245.

weight: The measure of the force with which bodies tend towards the earth's center, 22.

xylem (zī'lem): Vascular tissue that conducts water and mineral salts throughout the plant and provides it with mechanical support, 438.

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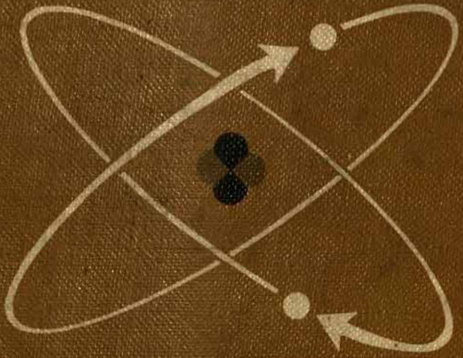

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